Introdução a Astronomia

Fabricio Ferrari, Sandro Rembold



- Origens, Antiguidade, Idade Média, Revolução científica;
- Terra, Lua, Sol, Sistema Solar, planetas;
- Constelações, movimento aparente dos astros, estações do ano;
- Via-Láctea, Galáxias, Universo em grande escala;

Origens





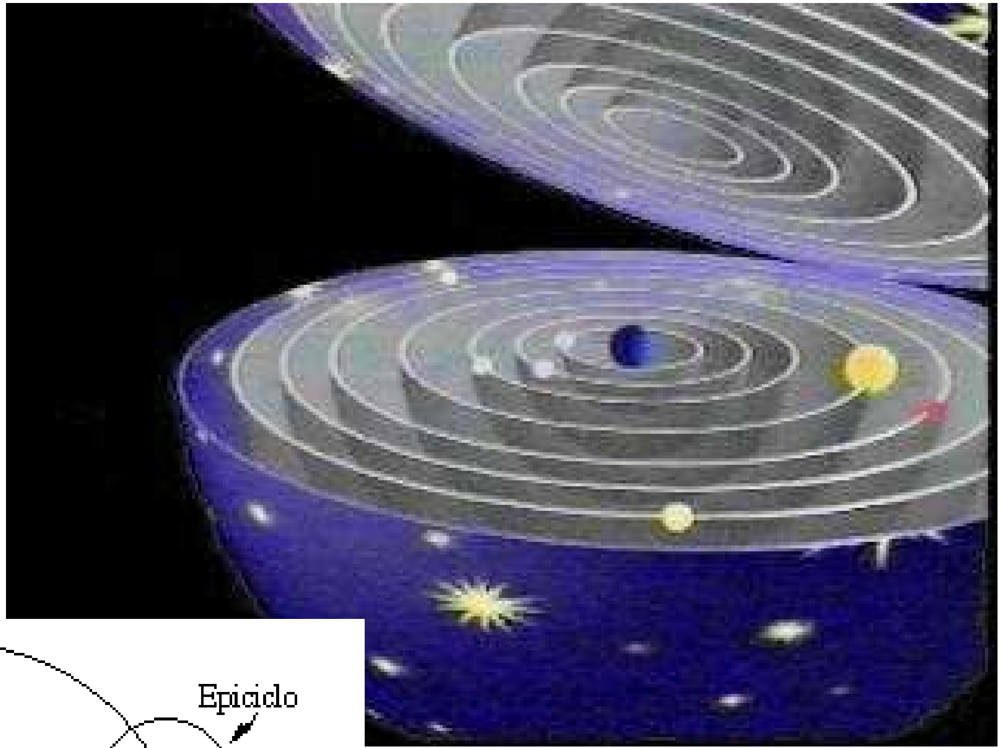
Almagesto-Ptolomeu

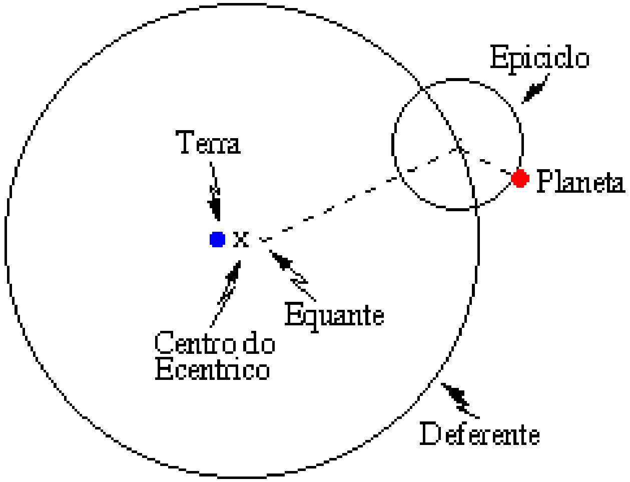
- Chineses, Babilônios, Assírios e Egípcios (3000ac);
- A ciência mais antiga;
- Calendários: medida do tempo, estações, agricultura.
- Religião, compreensão do Mundo.



Modelo Geocêntrico

- Grécia: Claudius Ptolomeu 100d.c.;
- Terra imóvel;
- astros perfeitos, eternos, imutáveis;
- Deuses no céu controlavam clima, colheita, ...
- Planetas moviam-se em esferas celestes.
- Depois dos planetas anjos, deuses.



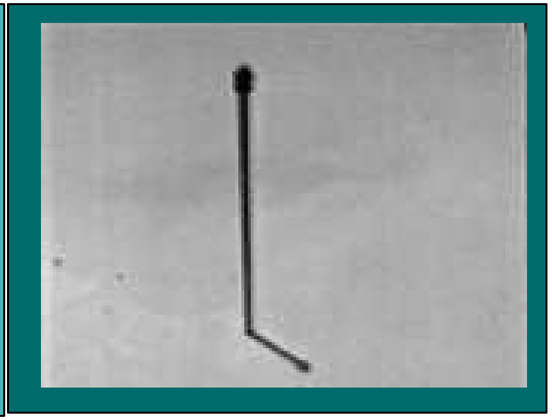


Diâmetro da Terra

(Erastótenes 276-194 ac)



Siena



Alexandria

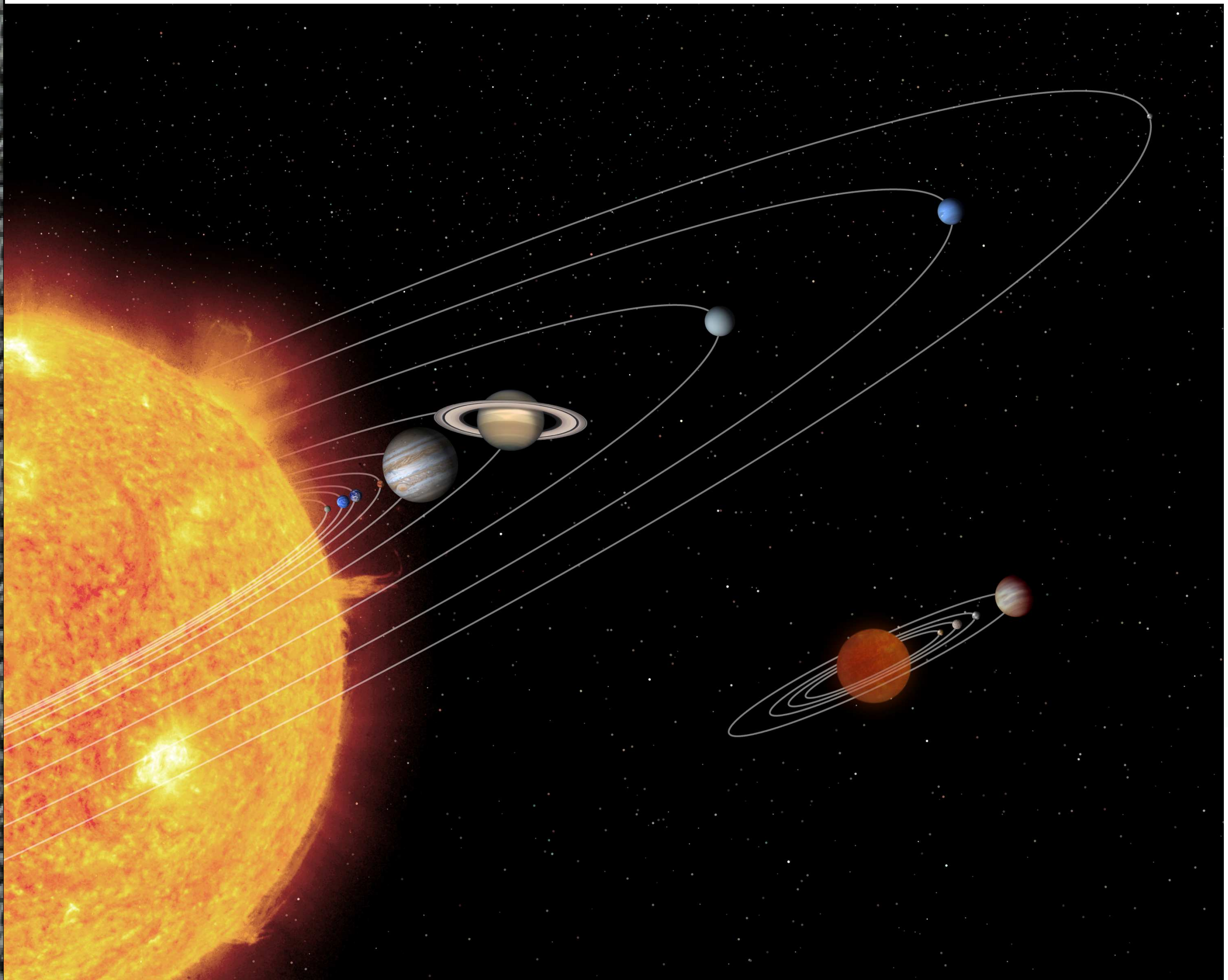
Diâmetro da Terra com erro de 1%

D ~ 6400 Km

Modelo Heliocêntrico

- Nicolau Copérnico ~ 1500
- Sol no centro do sistema Solar.
- Planetas girando em órbitas em torno do Sol.
- Terra como os outros planetas.
- Ordem dos Planetas a partir do Sol: Mercúrio, Vênus, Terra, Marte, Júpiter, Saturno, *(Urano, Netuno, Plutão)*.
- Explicação do movimento dos astros muito simplificada.
- Galileu Galilei, Giordano Bruno
- Isaac Newton

Sistema Solar



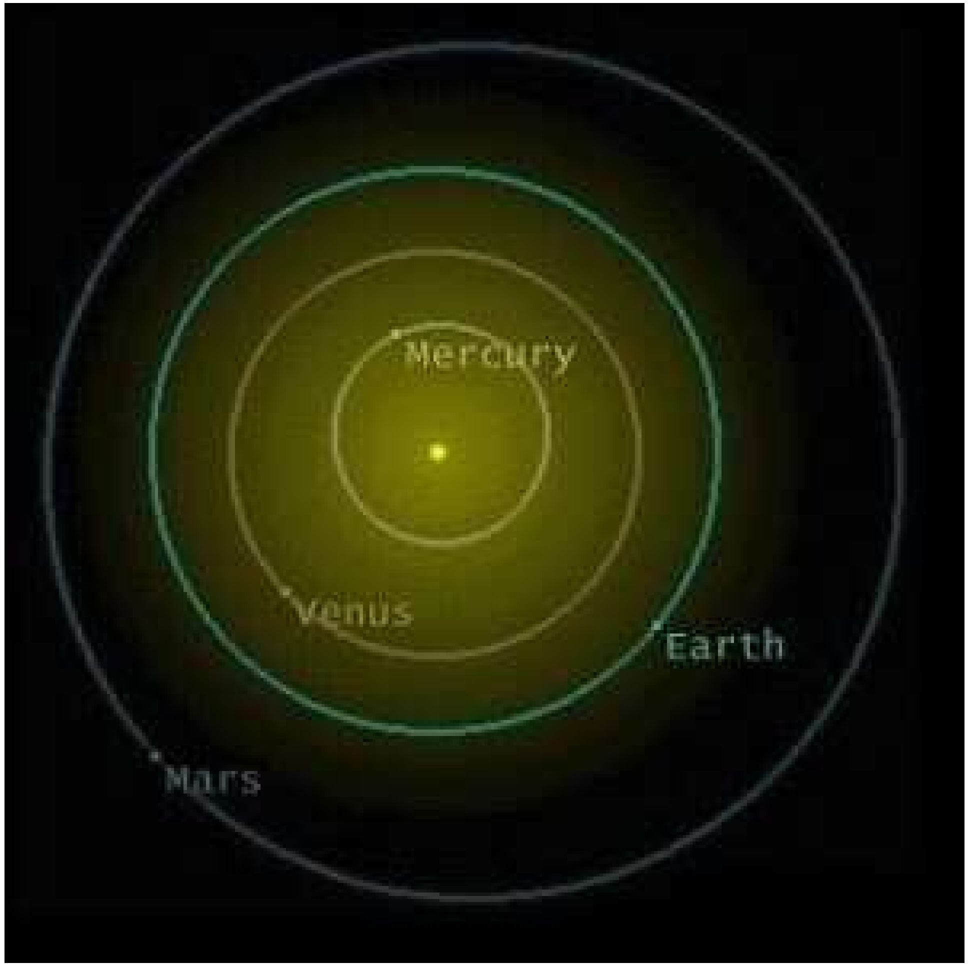
Massa no Sistema Solar

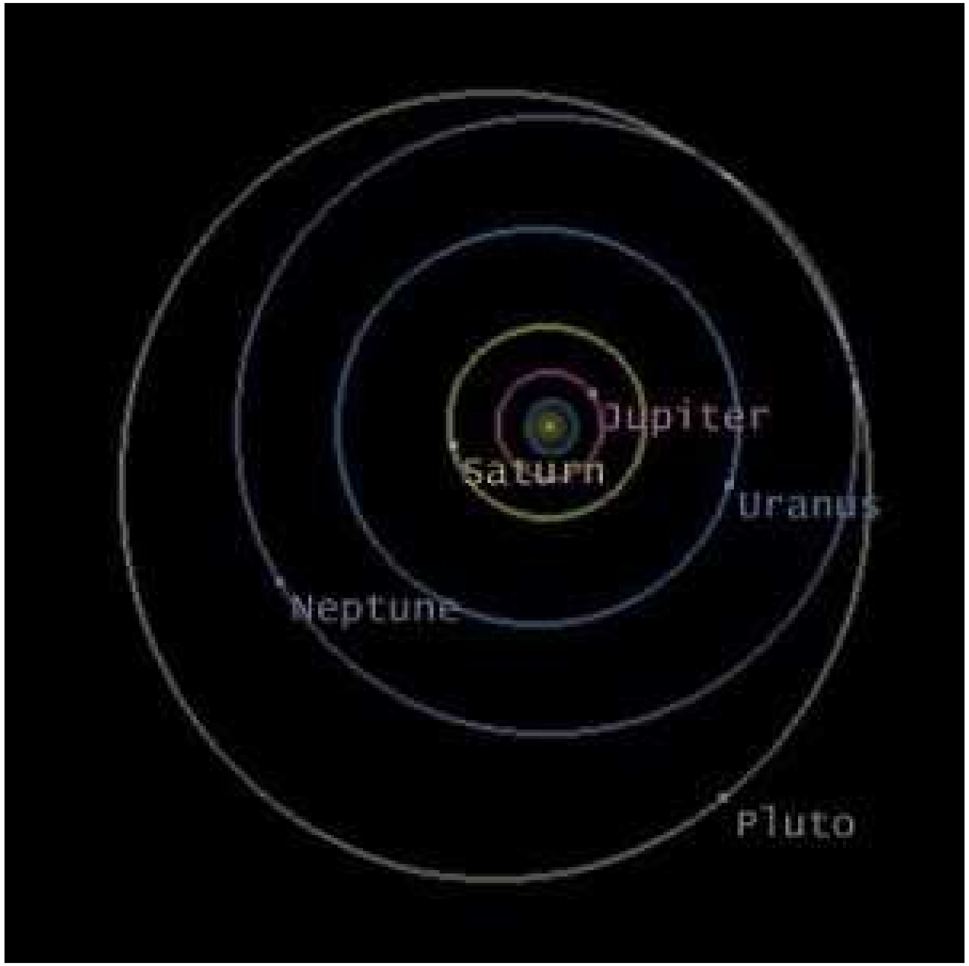
Componente	Massa
Sol	99,85%
Júpiter	0,10%
Demais planetas	0,04%
Cometas	0,01% (?)
Satélites e anéis	0,000 05%
Asteróides	0,000 000 2%
Meteoróides e poeira	0,000 000 1% (?)

Sistema Solar



Sistema Solar





	Mercurio	Venus	Terra	Marte	Jupiter	Saturno	Urano	Netuno	Plutão
Distância média ao Sol (UA)	0,387	0,723	1	1,524	5,203	9,539	19,18	30,06	39,44
Distância média ao Sol (10^6km)	57,9	108,2	149,6	227,9	778,4	1423,6	2867	4488	5909
Excentricidade da Órbita	0,206	0,0068	0,0167	0,093	0,048	0,056	0,046	0,010	0,248
Período de Revolução (d=dias, a=anos)	87,9d	224,7d	365,25d	686,98d	11,86a	29,46a	84,04a	164,8a	247,7a
Período de Rotação (d=dias, h=hora)	58,6d	–243d	23h56m	24h37m	9h48m	10h12m	–17h54m	19h6m	6d9h
Inclinação do Eixo	0,1°	177°	23° 27'	25° 59'	3° 05'	27° 44'	98°	30°	120°
Inclinação da Órbita em Relação Eclíptica	7°	3,4°	0°	1,9°	1,3°	2,5°	0,8°	1,8°	17,2°
Diâmetro Equatorial (km)	4878	12100	12756	6786	142984	120536	51108	49538	2350
Massa (kg)	$3{,}30\times10^{23}$	$4{,}87\times10^{24}$	$5{,}97\times10^{24}$	$6{,}42\times10^{23}$	$1{,}90\times10^{27}$	$5{,}69\times10^{26}$	$8{,}70\times10^{25}$	$1{,}03\times10^{26}$	$1{,}3\times10^{22}$
Massa (M_{Terra})	0,055	0,815	1	0,107	317,9	95,2	14,6	17,2	0,002
Densidade (g/cm^3)	5,4	5,2	5,5	3,9	1,3	0,7	1,3	1,6	2,0
Achatamento	0	0	0,003	0,005	0,06	0,1	0,03	0,02	–
Temperatura (C) (S=Sólido, n=nuvens)	407(S)dia –183(S)noite	–43(n) 470(S)	22(S)	–23(S)	–150(n)	–180(n)	–210(n)	–220(n)	–218(S)
Principais Componentes Atmosfera	traços de Na,He,H,O	98% CO_2, 3,5% N	78% N_2, 21% O_2	95% CO_2, 3% N	90% H, 10% He	97% H, 3% He	83% H, 15% He,CH_4	74% H, 25% He,CH_4	CH,N,CO
Gravidade Superficial em relação à Terra (g_{Terra})	0,37	0,88	1	0,38	2,64	1,15	1,17	1,18	0,11
No. de Satélites Conhecidos	0	0	1	2	28	30	21	8	1
Velocidade de Escape (km/s)	4,3	10,4	11,2	5,0	60	35,4	21	24	1,21

Escala comparativa

astro	tamanho	comparação	posição
Sol	2 cm	bola ping-pong	0
Terra	0.02 cm	semente papoula	5 m
Júpiter	0.2 cm	pimenta	26 m
Plutão	0.004 cm	farelo	200 m
Próx Cen.	0.3 cm	pimenta	1200 km (São Paulo)

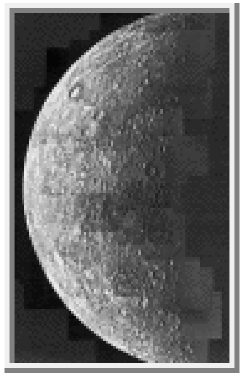
Planetas Terrestres

- Mercúrio, Vênus, Terra, Marte;
- Pequena Massa ($M \sim M_{terra}$)
- Densidade ~ 5 g/cm^3
- Rochas, metais pesados
- Poucos Satélites

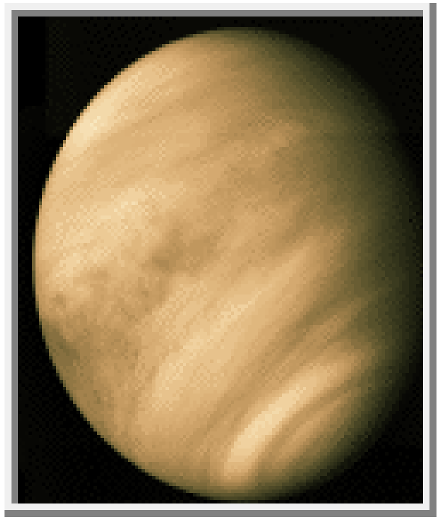
Terra



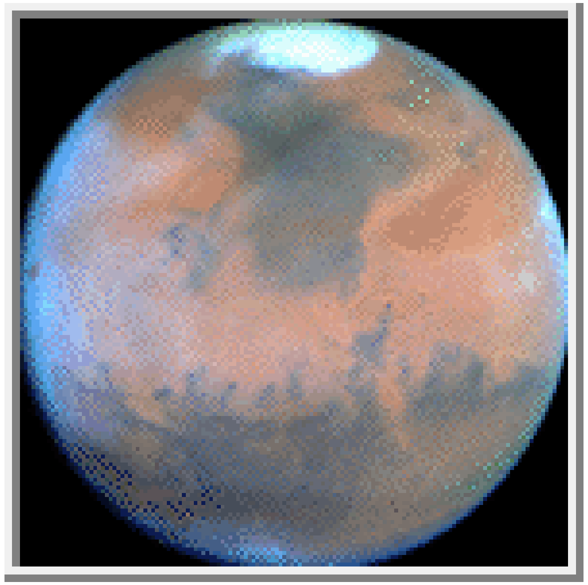
Mercúrio



Vênus



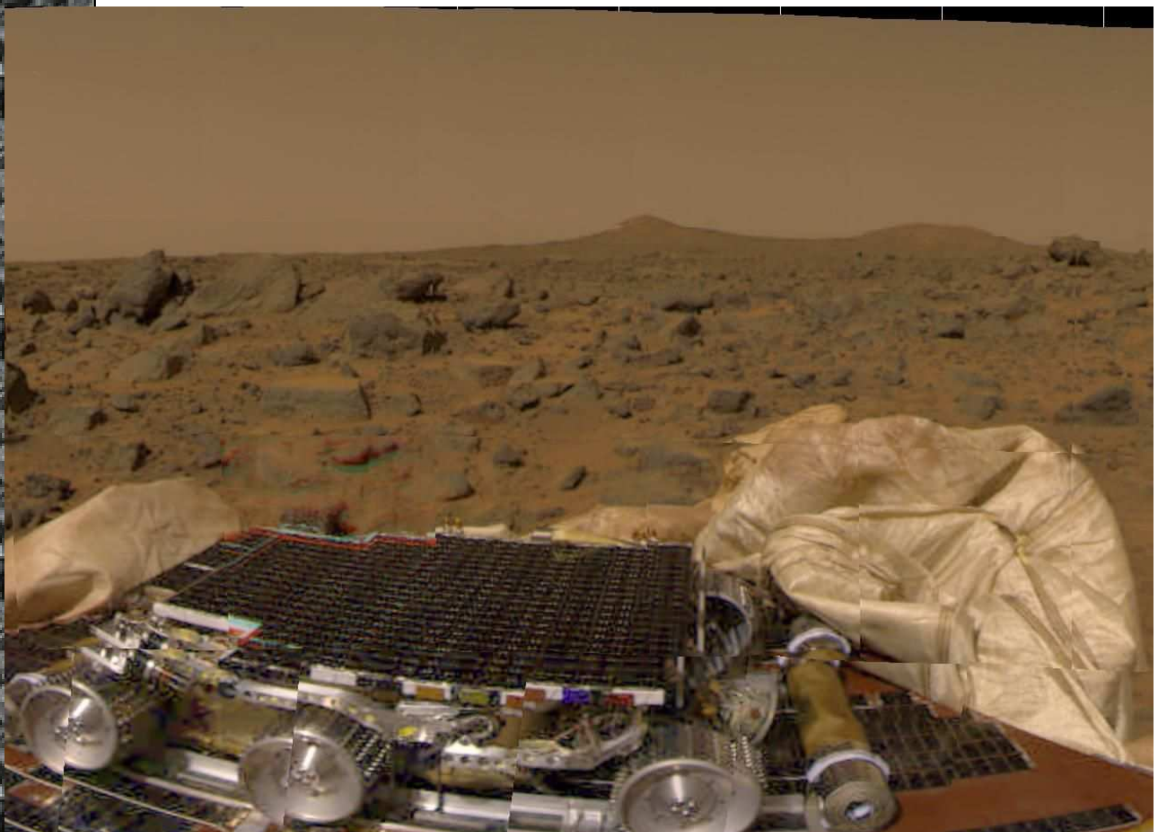
Marte

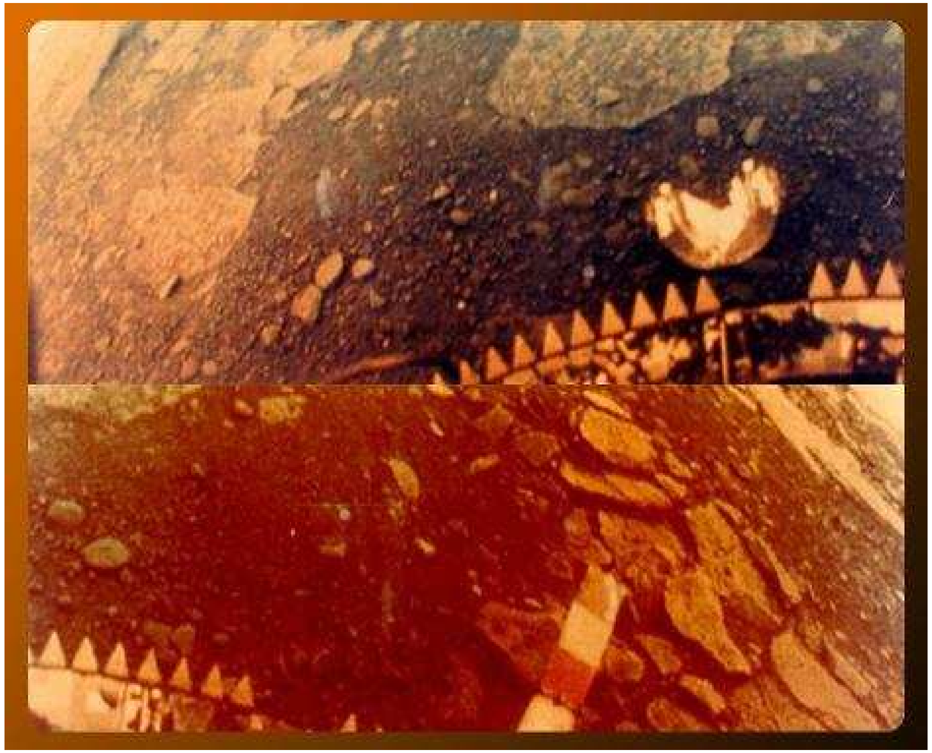


(fora de escala)

Planetas Terrestres

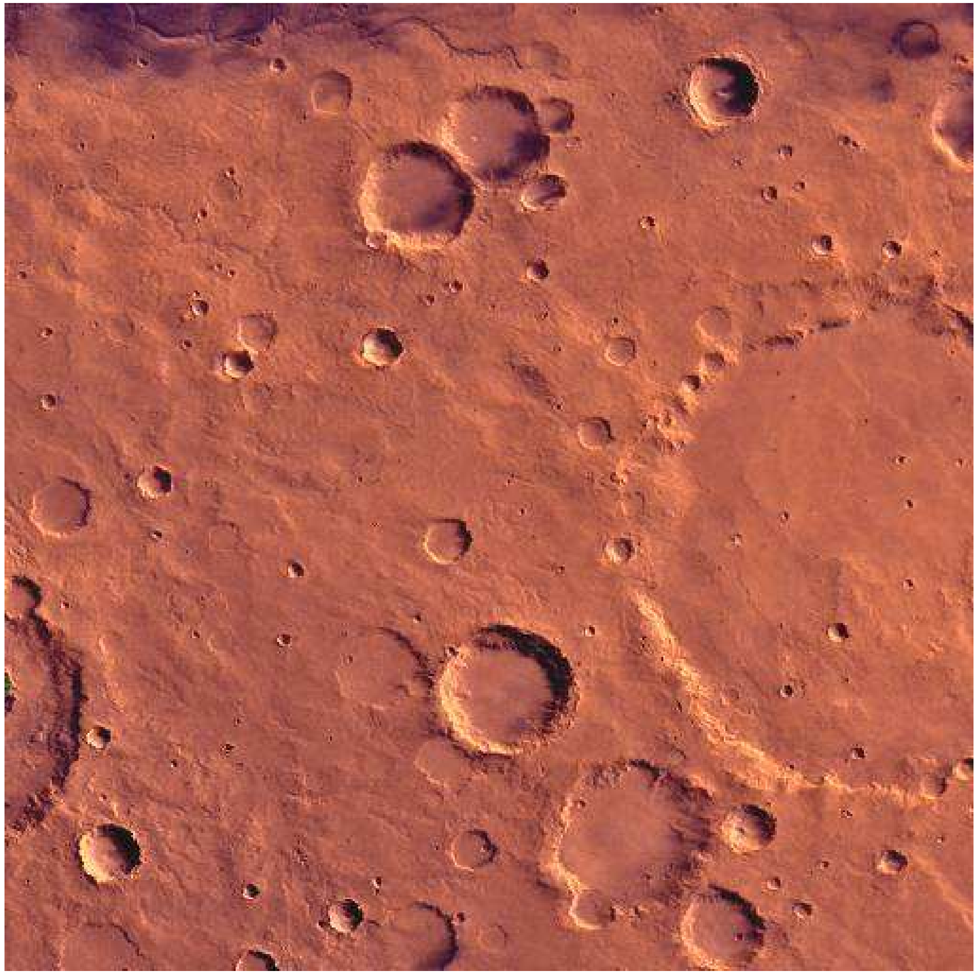
Marte





Vênus

Planetas Terrestres



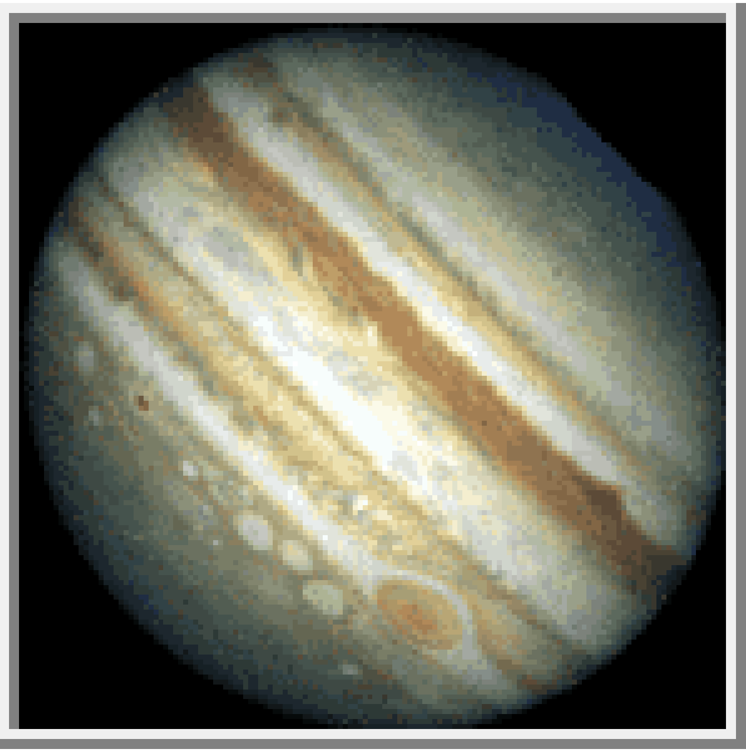


Terra

Marte

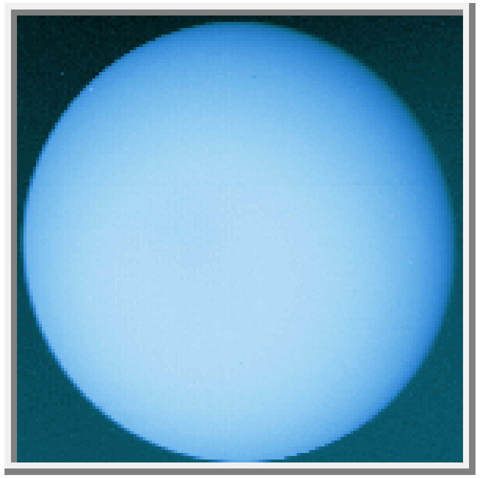
Planetas Jovianos

- Júpiter, Saturno, Urano, Netuno
- Grande Massa ($M_{Terra}<M<M_{Júpiter}$)
- Densidade ~ 1 g/cm³
- H, He, água, metano, amônia
- Muitos Satélites



Júpiter

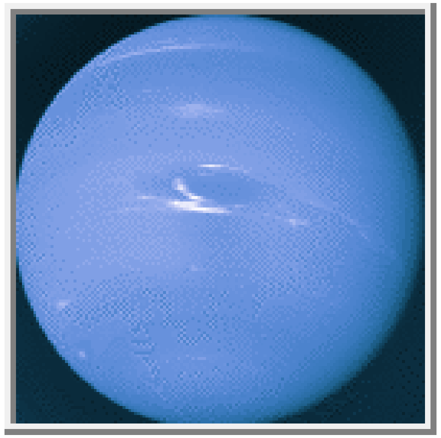
Urano



Saturno

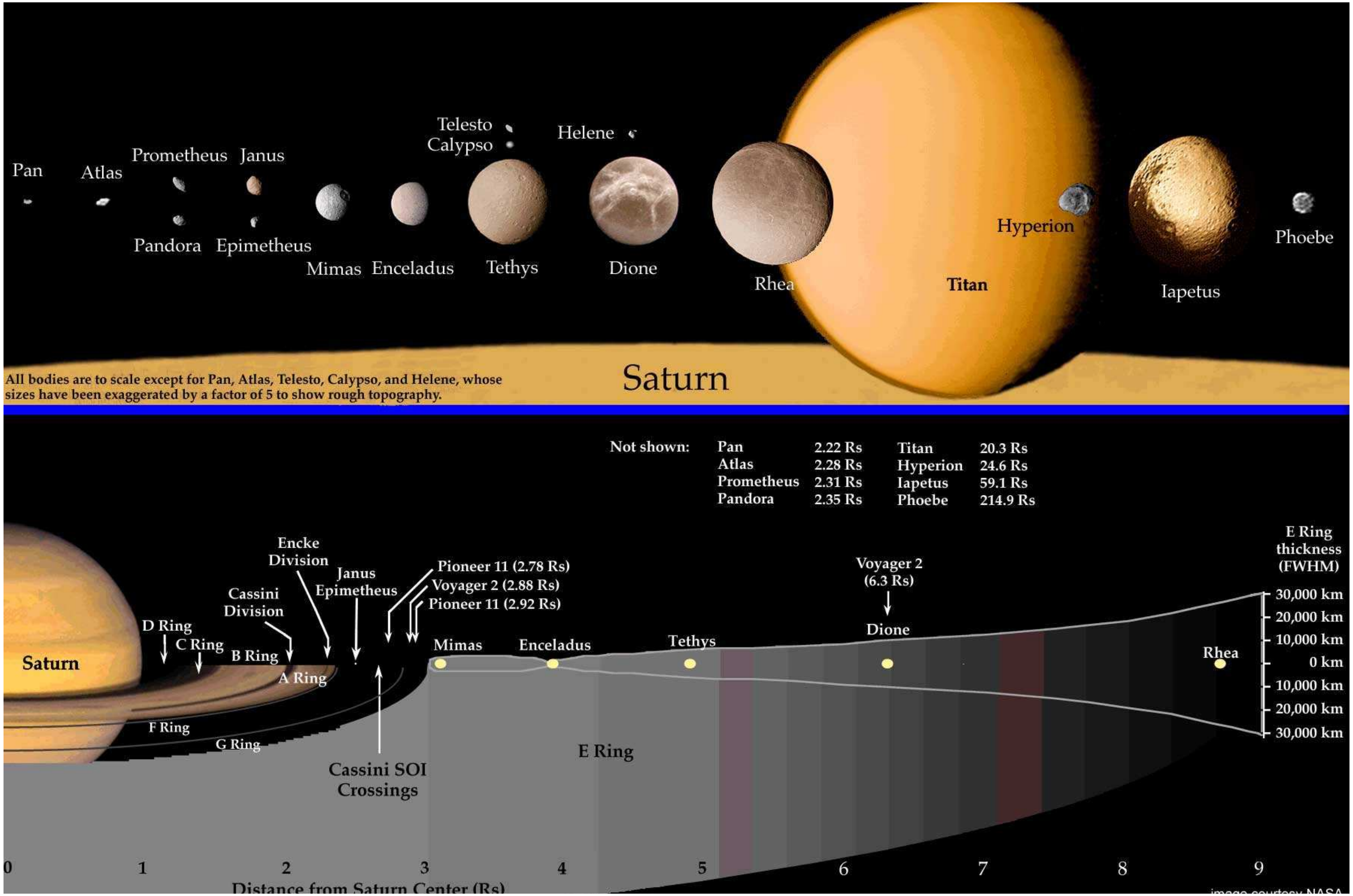


Netuno

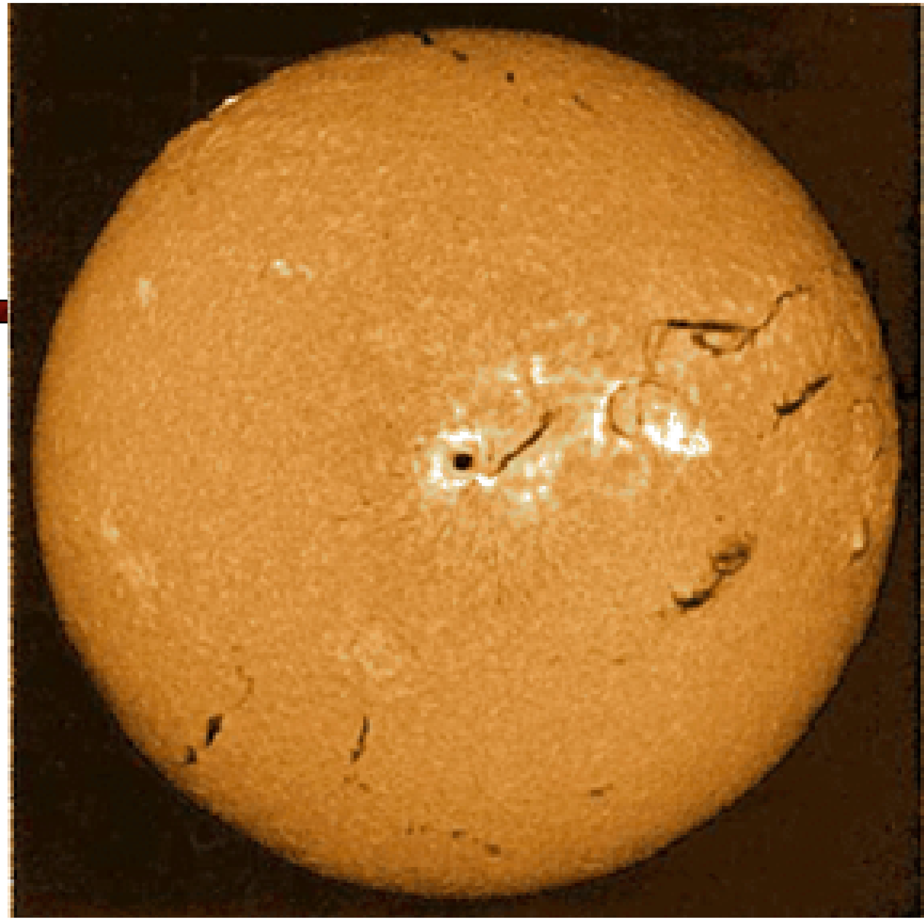


(fora de escala)

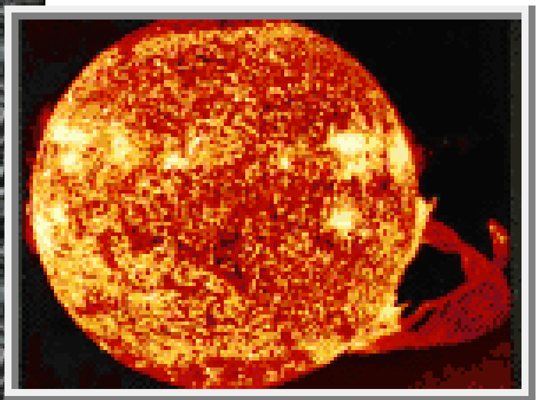
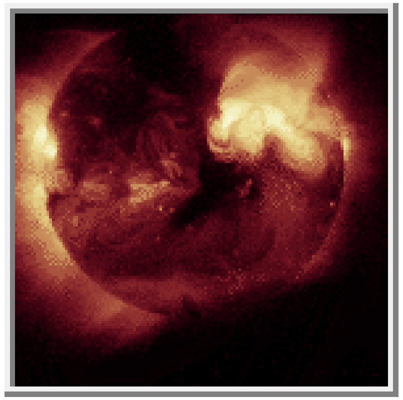
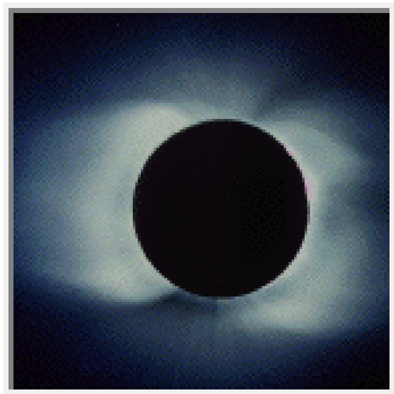
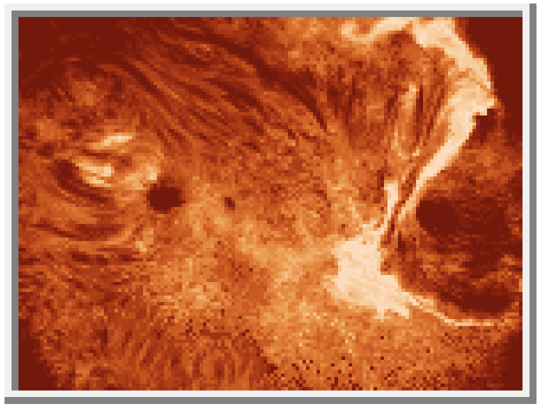
Planetas Jovianos



Nossa Estrela
O Sol

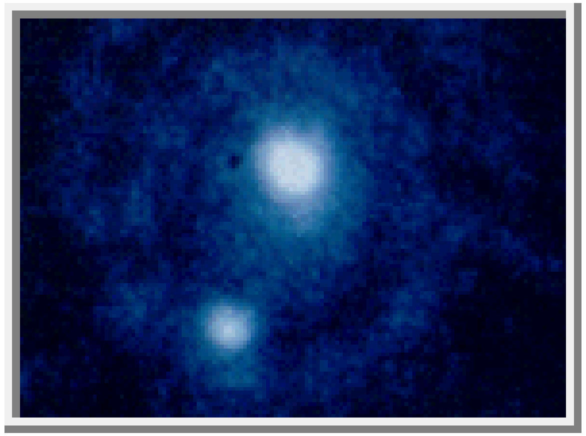


Massa ~ 10^{30} Kg
Diâm. ~ 7.10^{28} m
D_{sol} = 120 D_{terra}
T superf. = 5500 K
T central = 1.5 10^{7} K

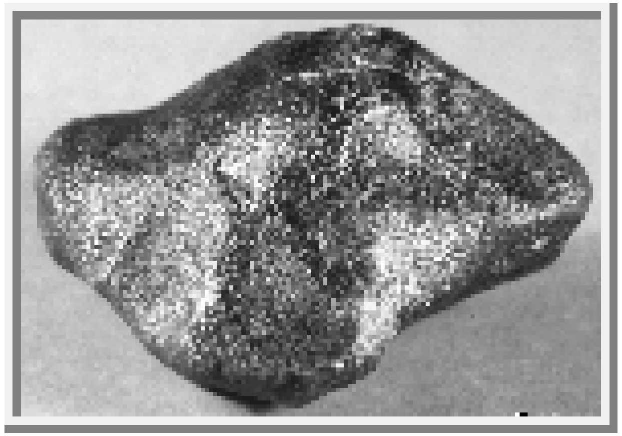





Outros Corpos

Plutão (planeta) e Charonte



Vesta (meteorito)



Gaspra (asteróide)

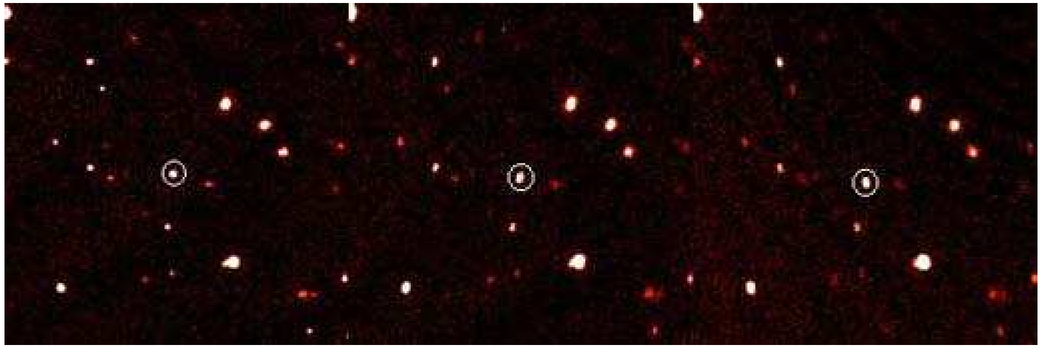


West 1975(cometa)



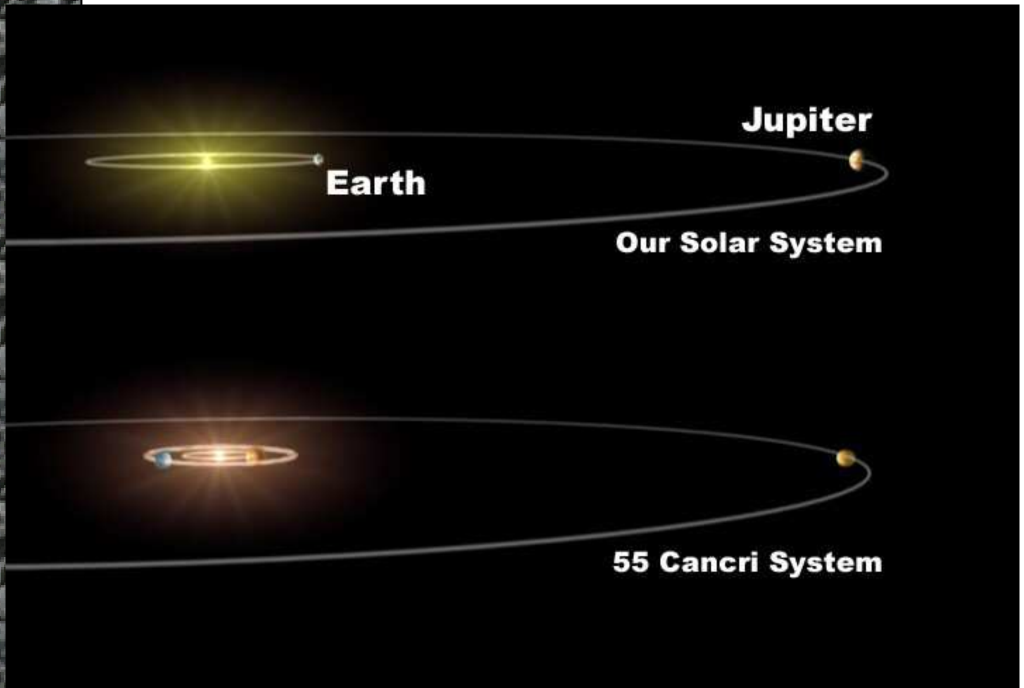
Outros Corpos

2003UB313



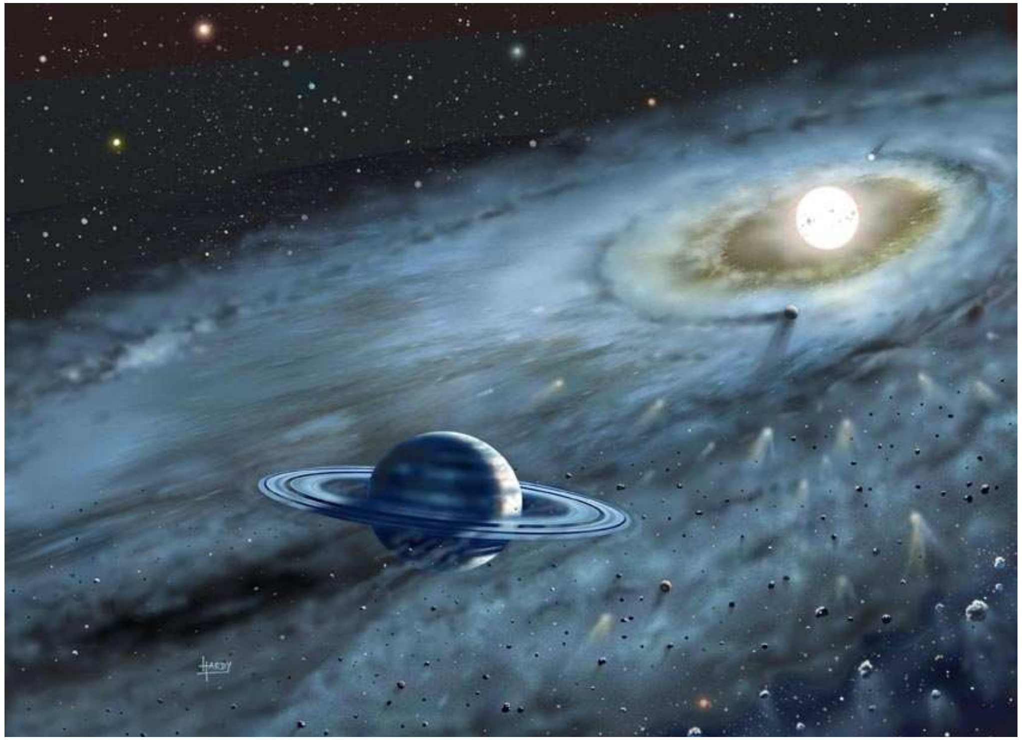


Outros sistemas planetários

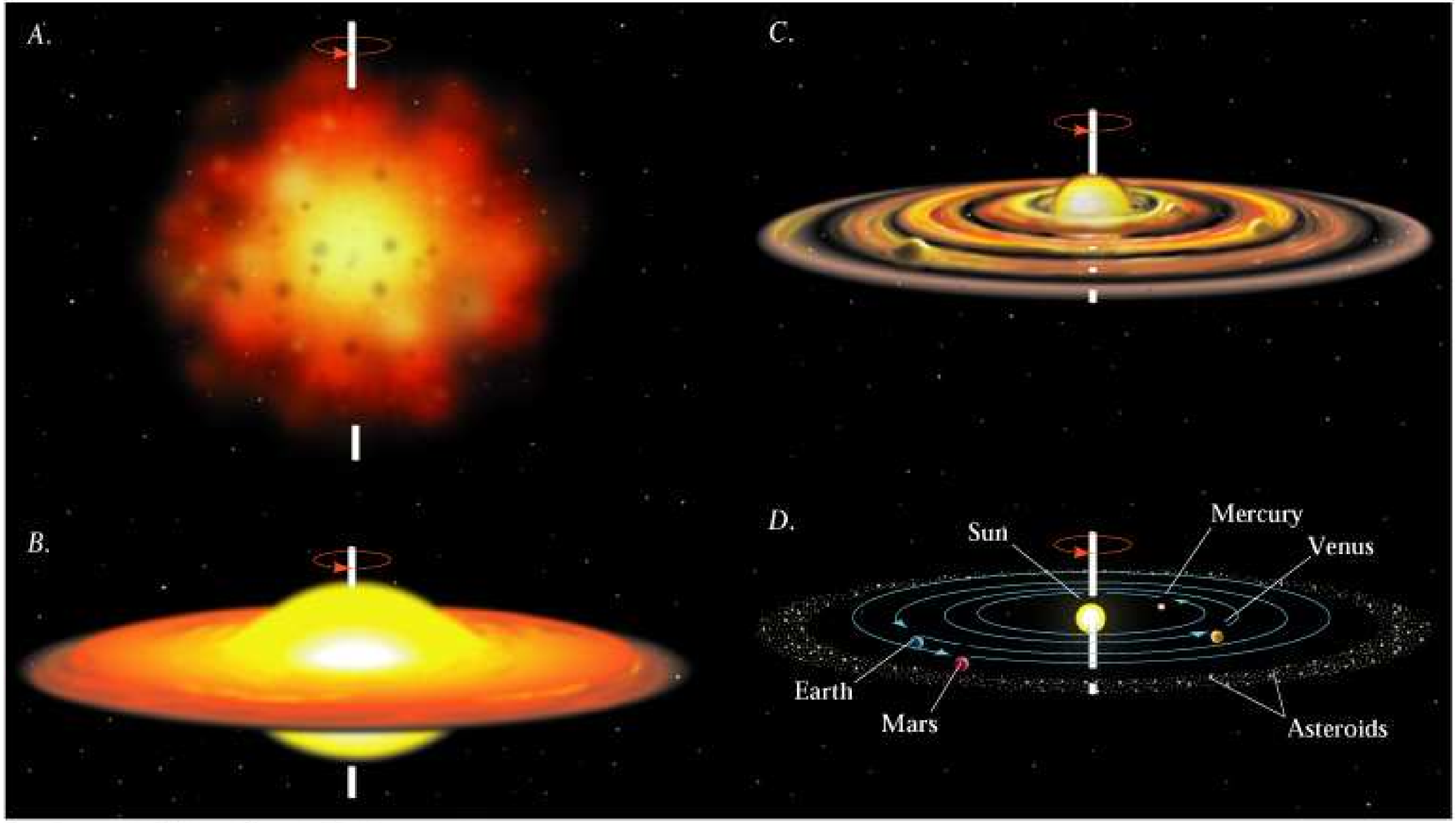


55 Cancri

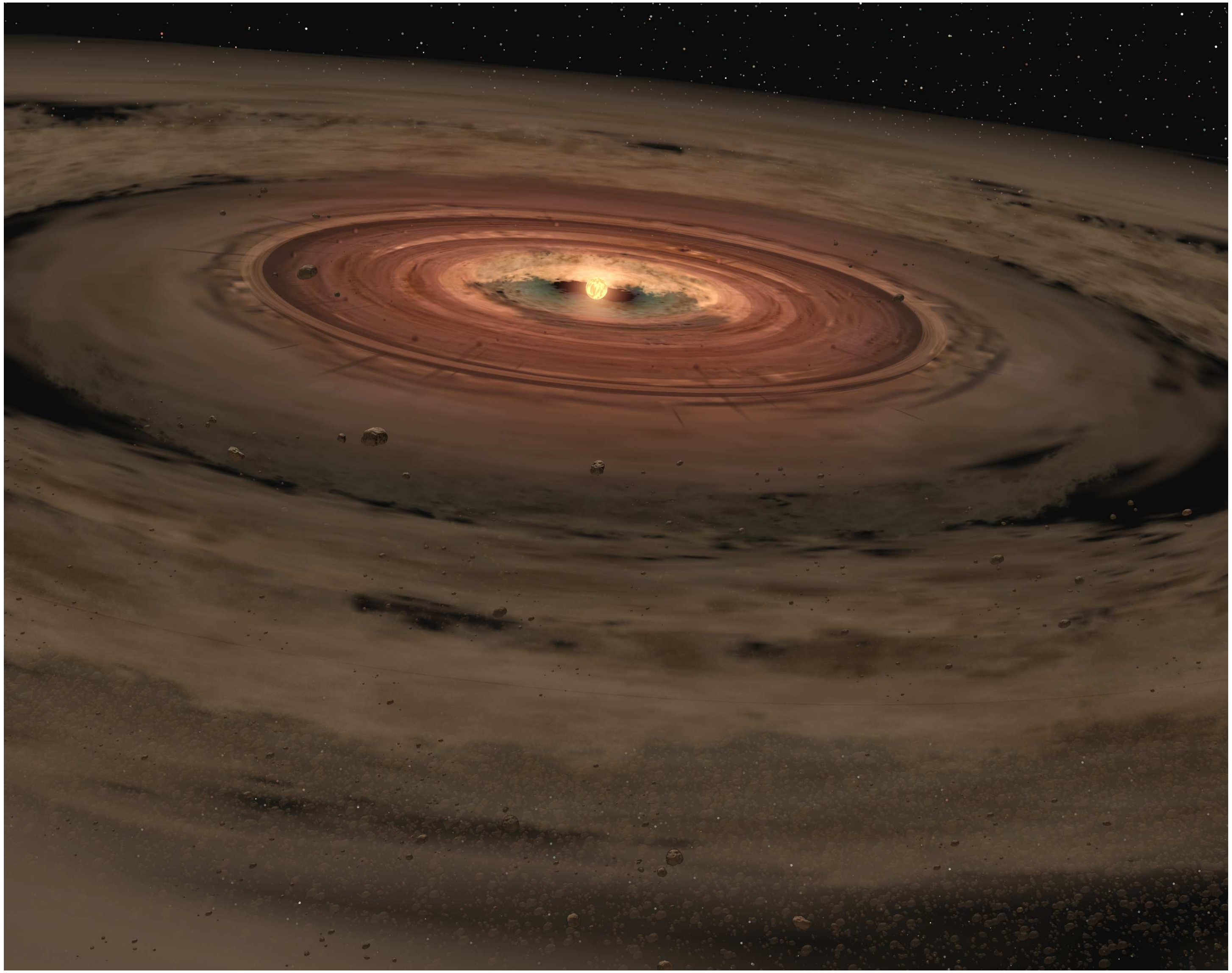
Fomalhaut



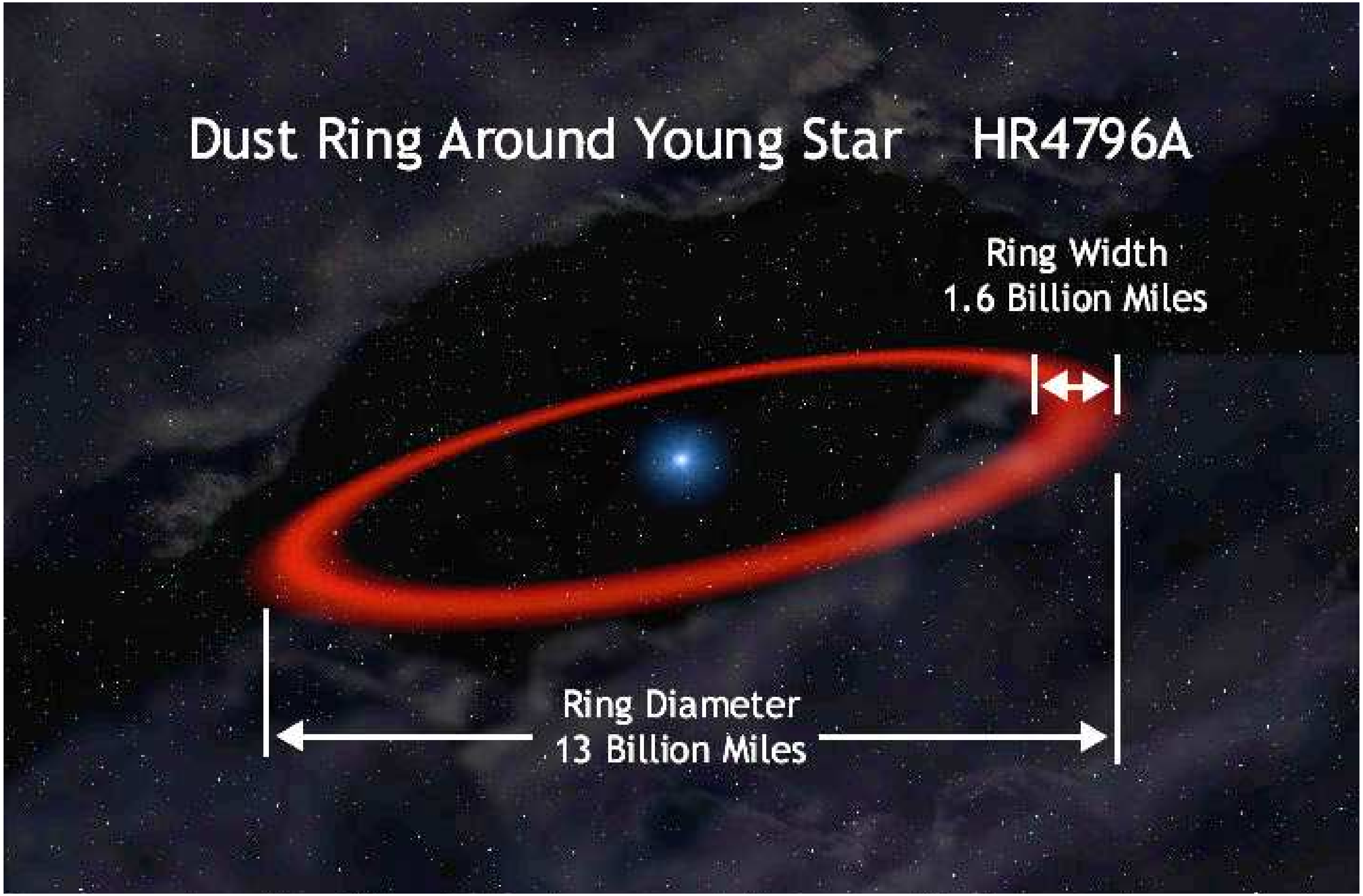
Formação do sistema solar



Formação do sistema solar

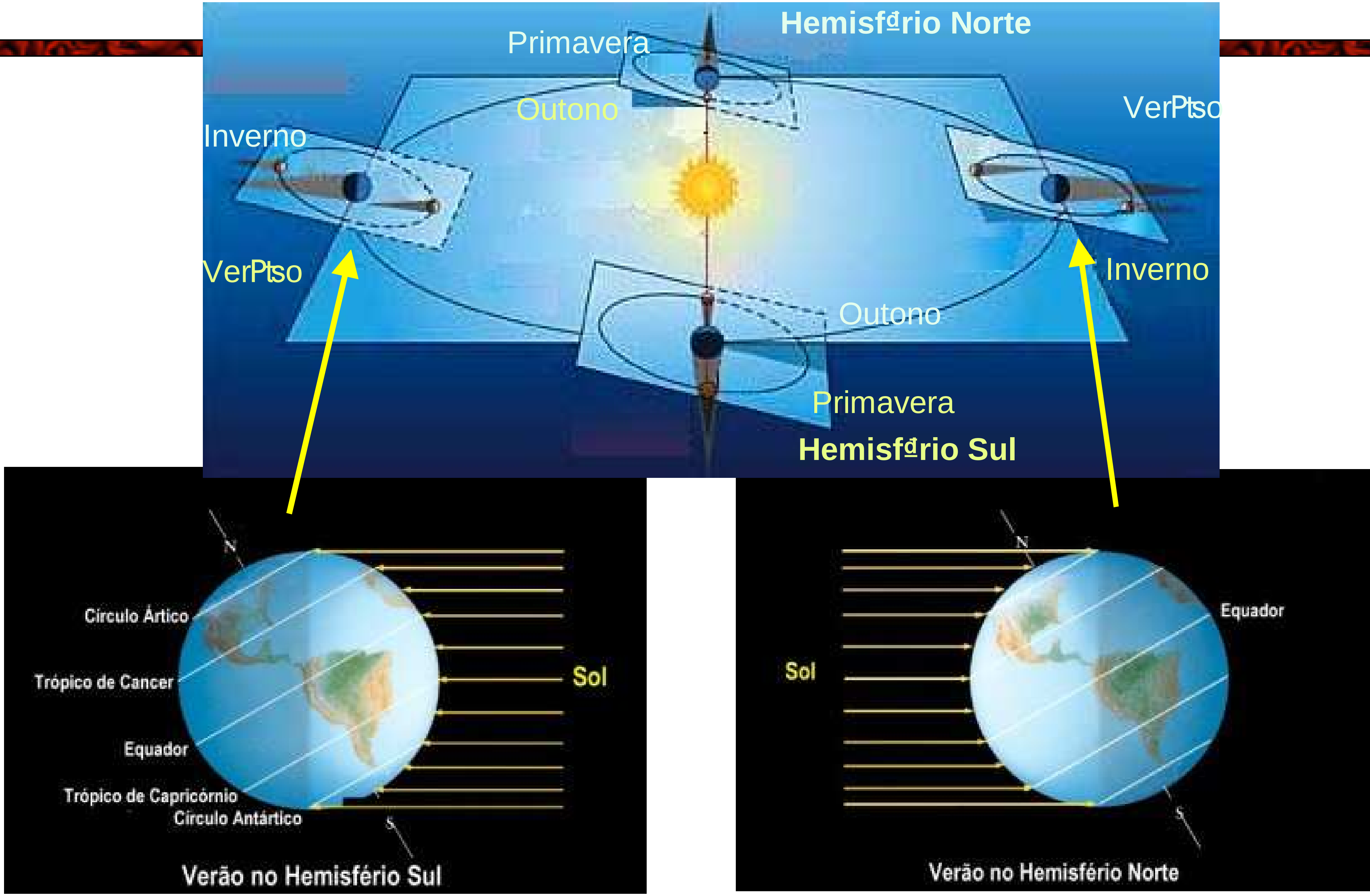


Formação do sistema solar



Estações do Ano

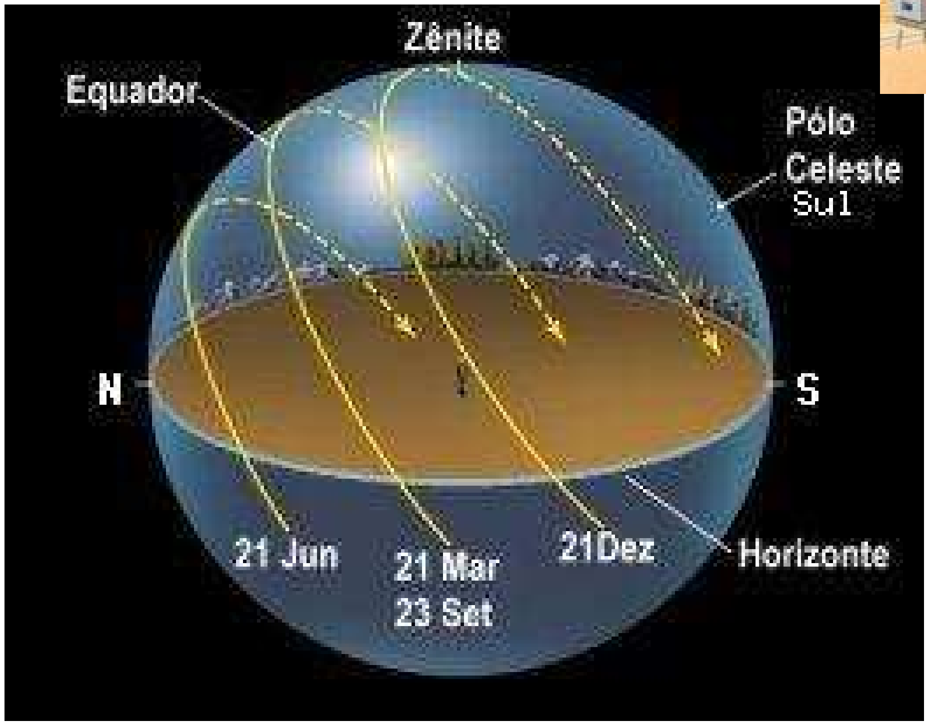
movimento anual da Terra

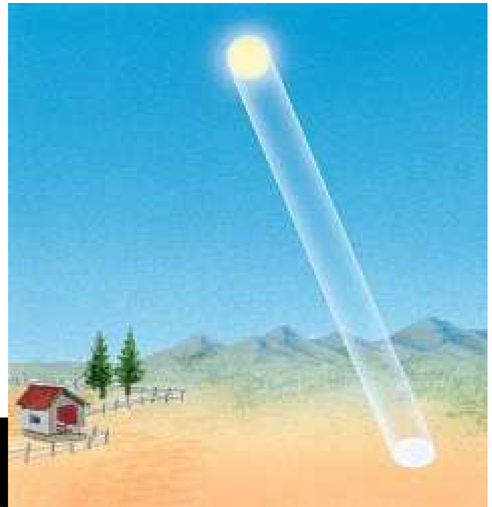


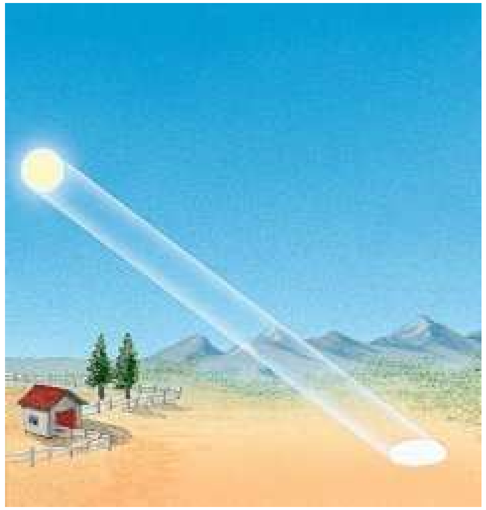
Estações do Ano

movimento aparente do Sol

As estações não tem nada que ver com a distância Terra-Sol (a órbita da Terra é quase circular)

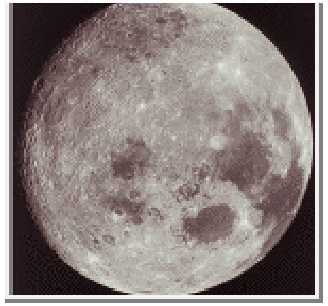


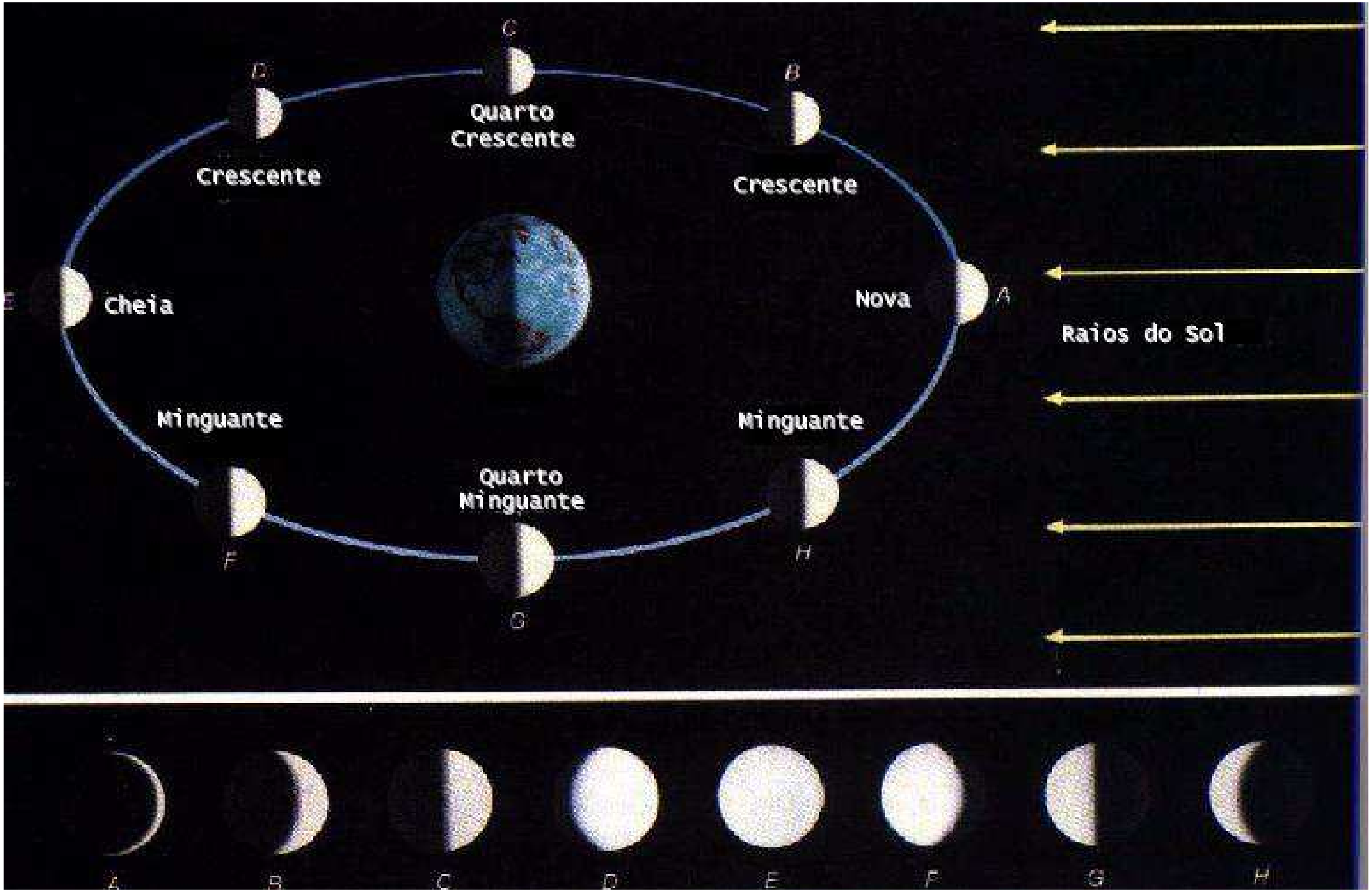




- A insolação depende da inclinação dos raios do Sol em relação ao chão.
- A duração do dia depende da trajetória aparente do Sol.

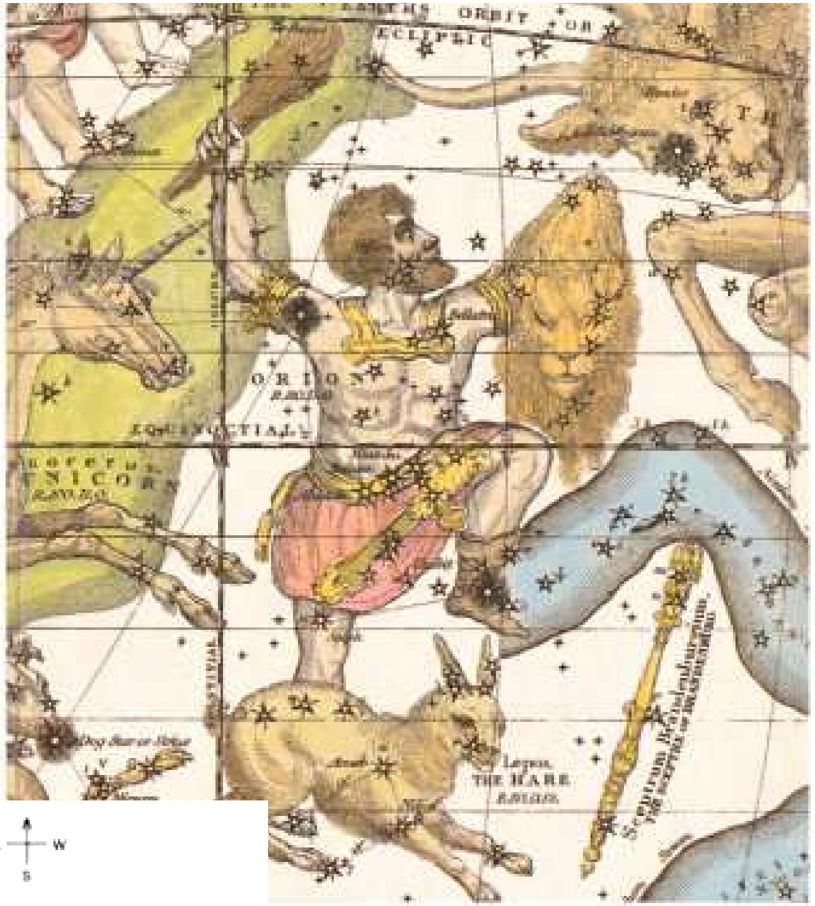
Fases da Lua

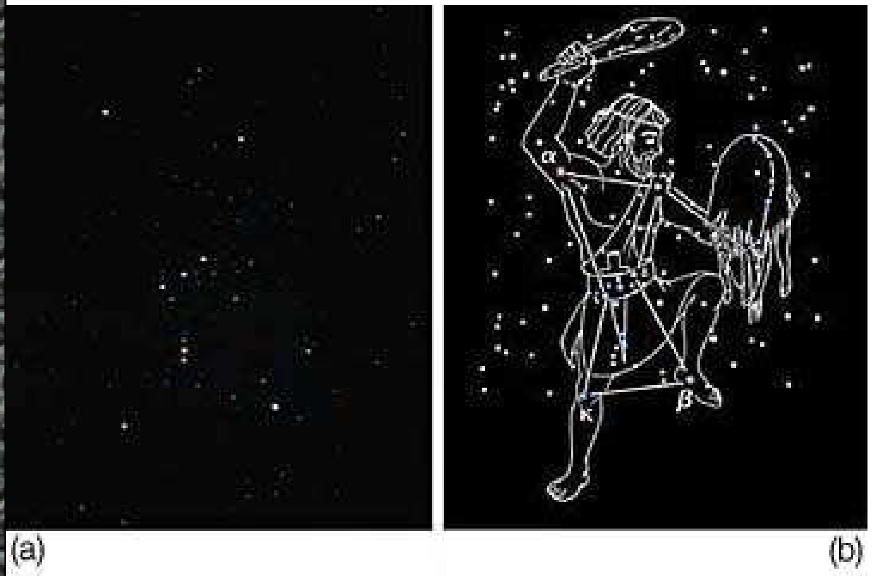


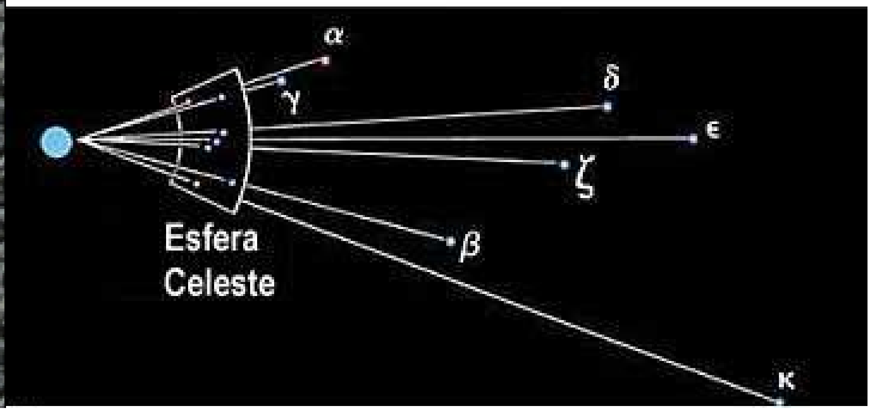


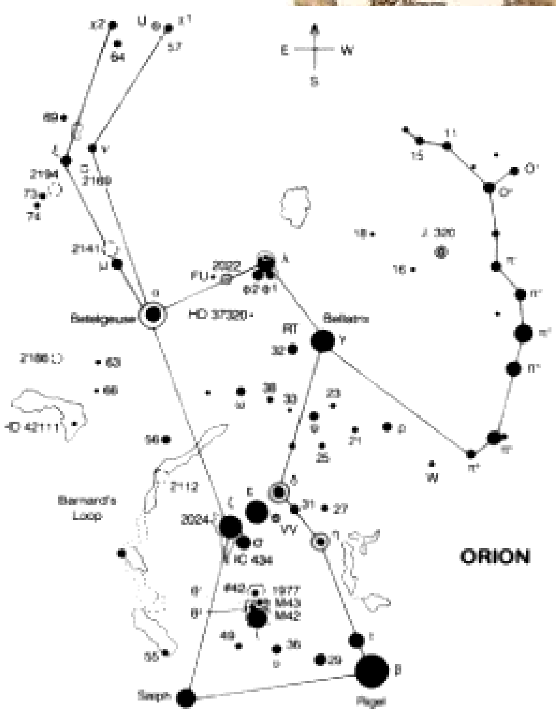
C
D
B
Quarto
Crescente
Crescente
Crescente
Cheia
Nova
A
Raios do Sol
Minguante
Minguante
Quarto
Minguante
F
H
G

Constelações

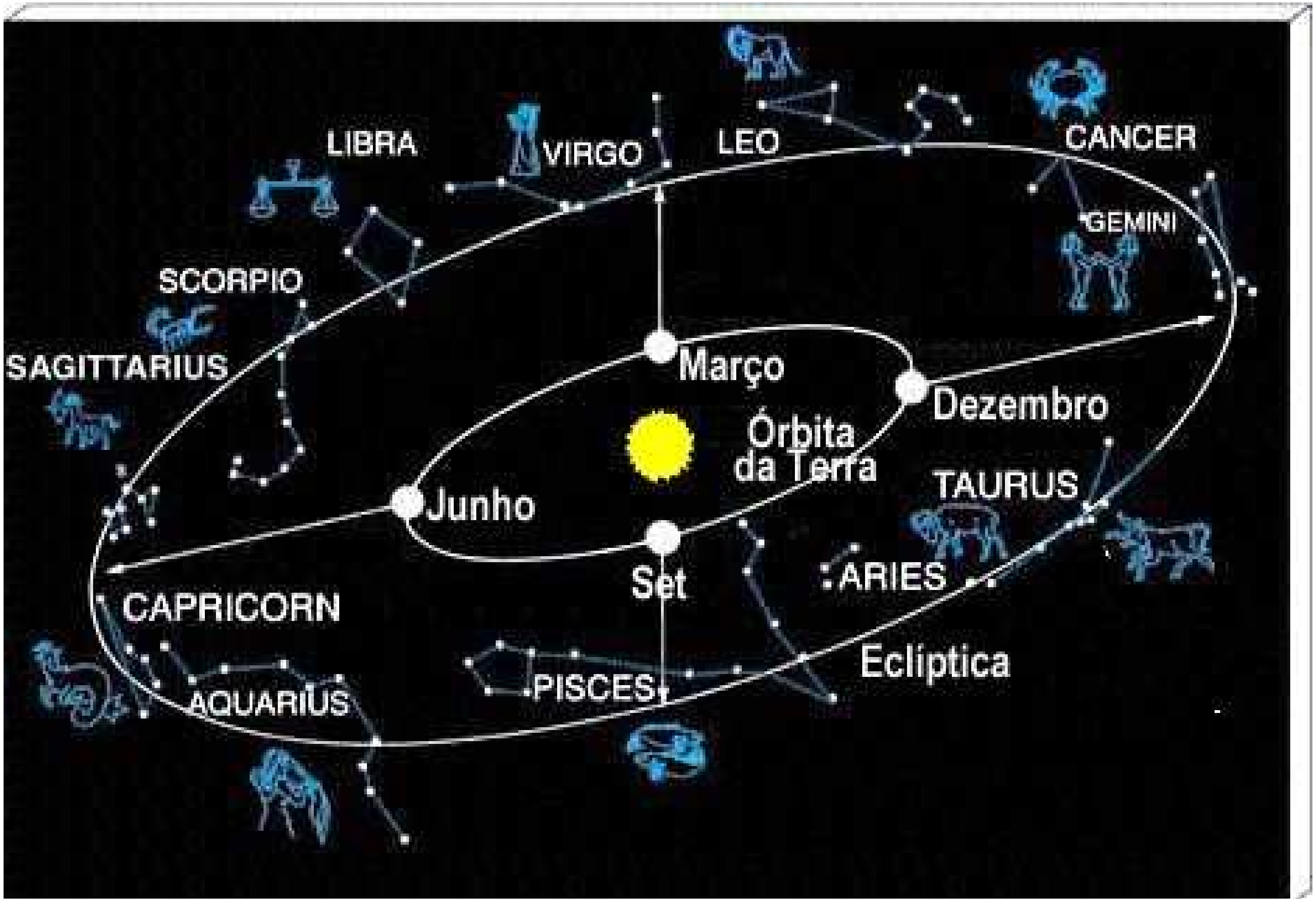








Zodíaco



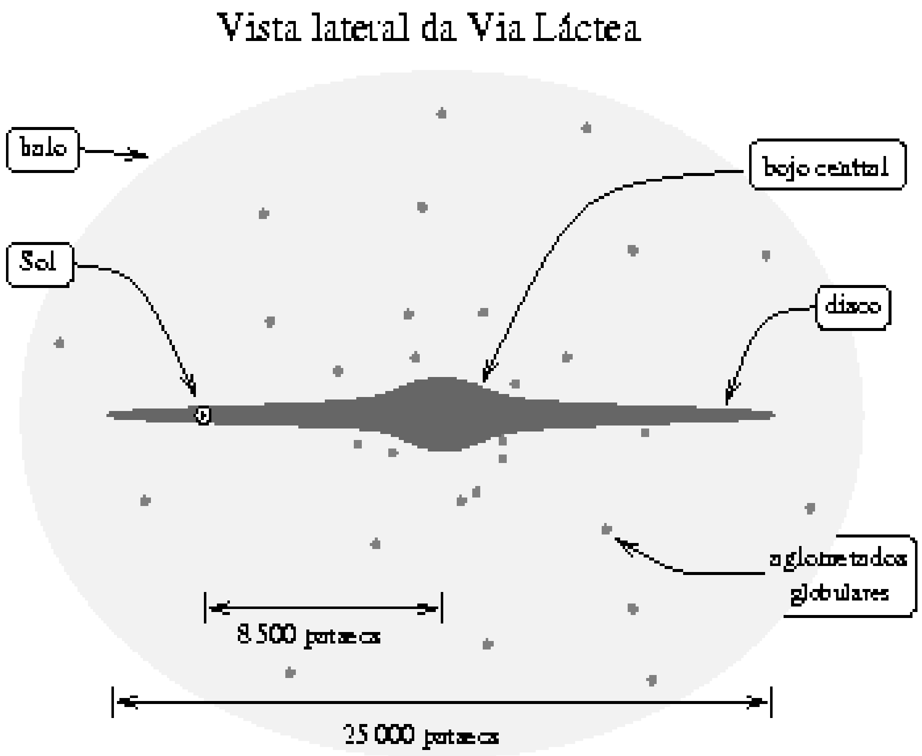
LIBRA
VIRGO
LEO
CANCER
GEMINI
SCORPIO
SAGITTARIUS
Março
Dezembro
Órbita da Terra
Junho
TAURUS
Set
ARIES
CAPRICORN
Eclíptica
AQUARIUS
PISCES

Via-Láctea



M31

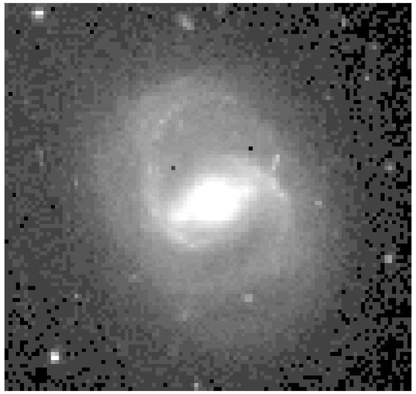




Estrelas, gás, poeira
Diâm. ~ 100.000 anos-luz
10^{11} estrelas
M ~ 10^{41} Kg

Outras Galáxias

Espirais:





Sa



Sb



Sc

Esferoidais:





E0



E3

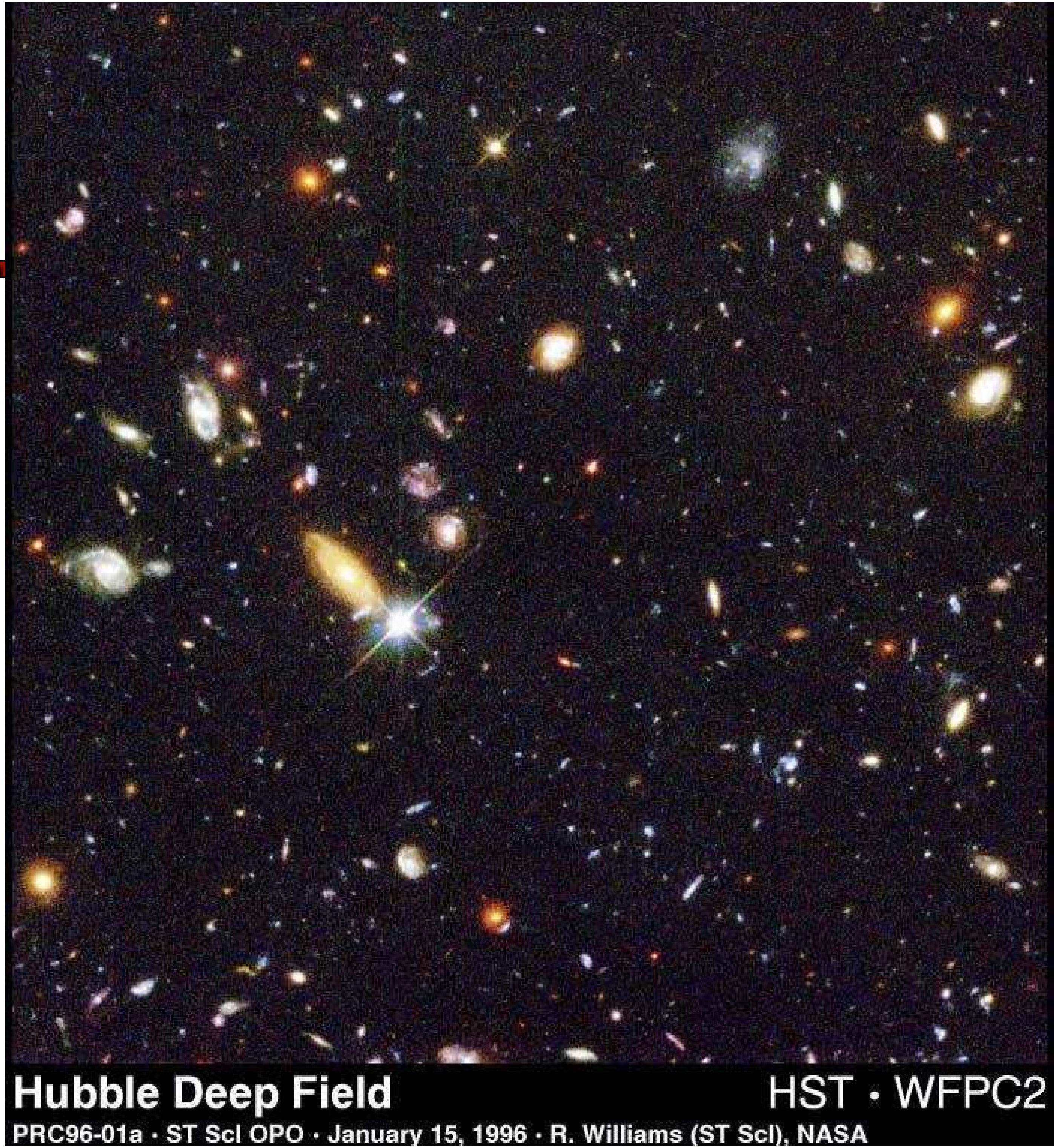


E6

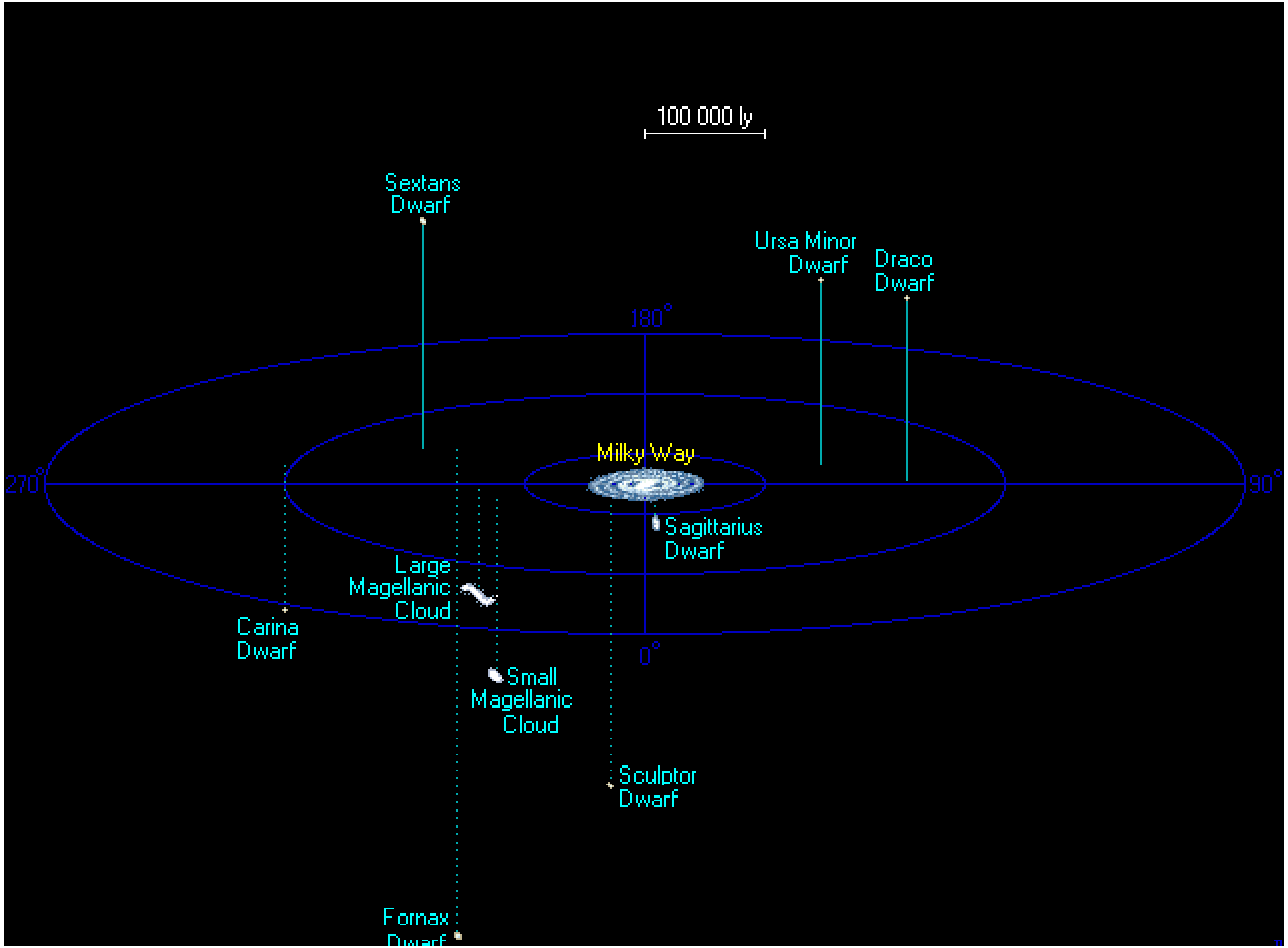
regulares:



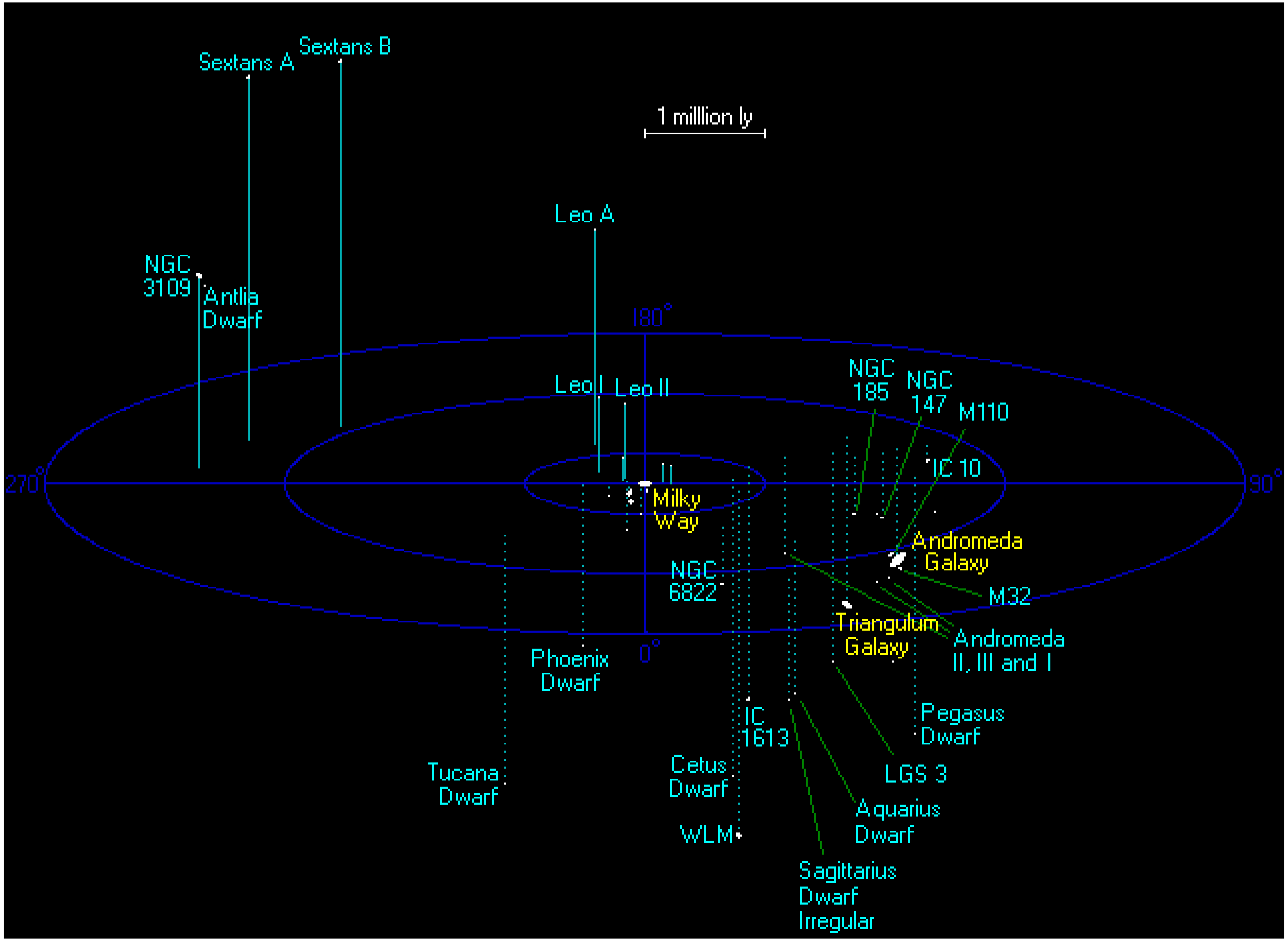



Hubble Deep Field
HST • WFPC2
PRC96-01a • ST ScI OPO • January 15, 1996 • R. Williams (ST ScI), NASA

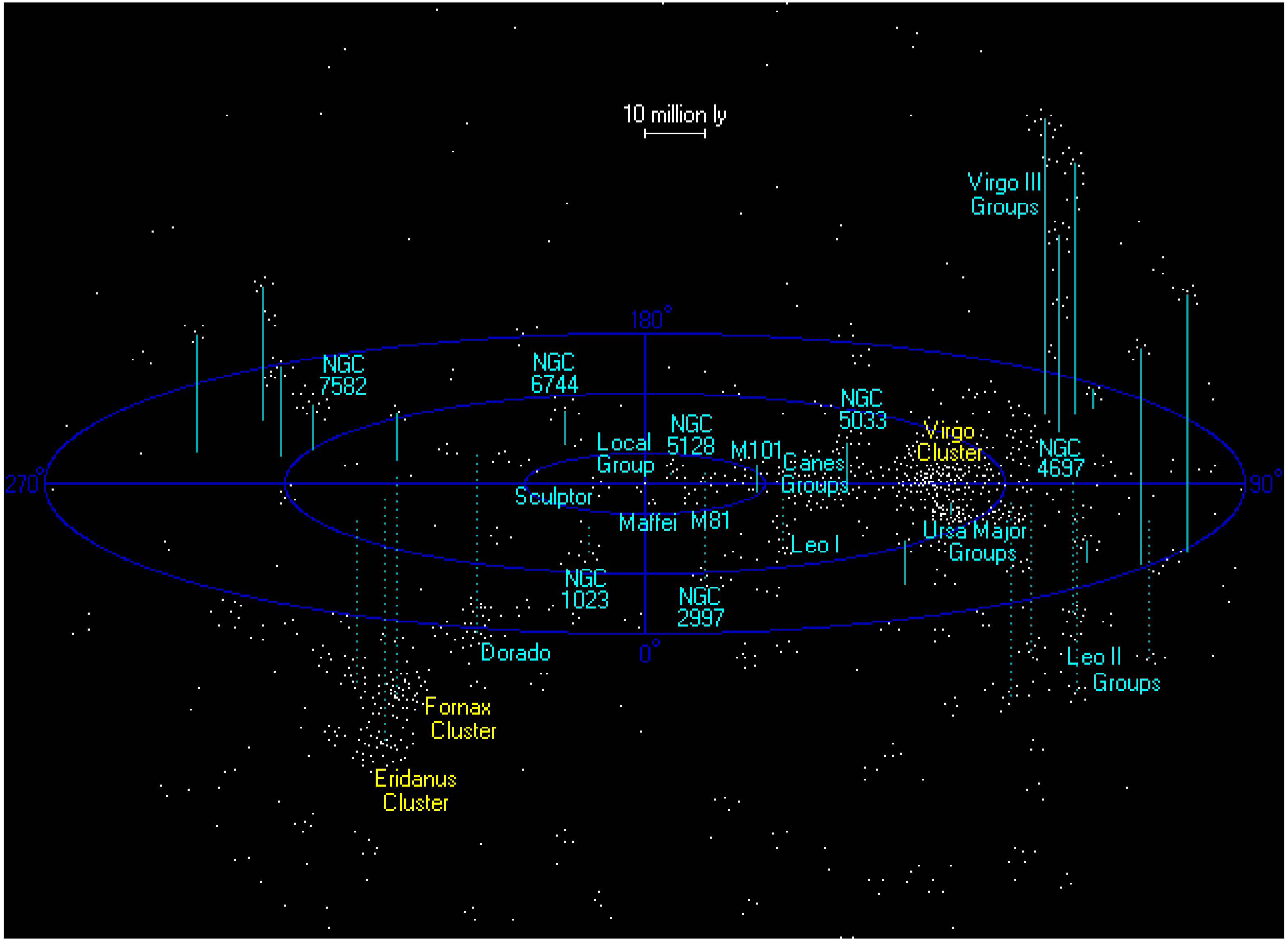
O Grupo Local



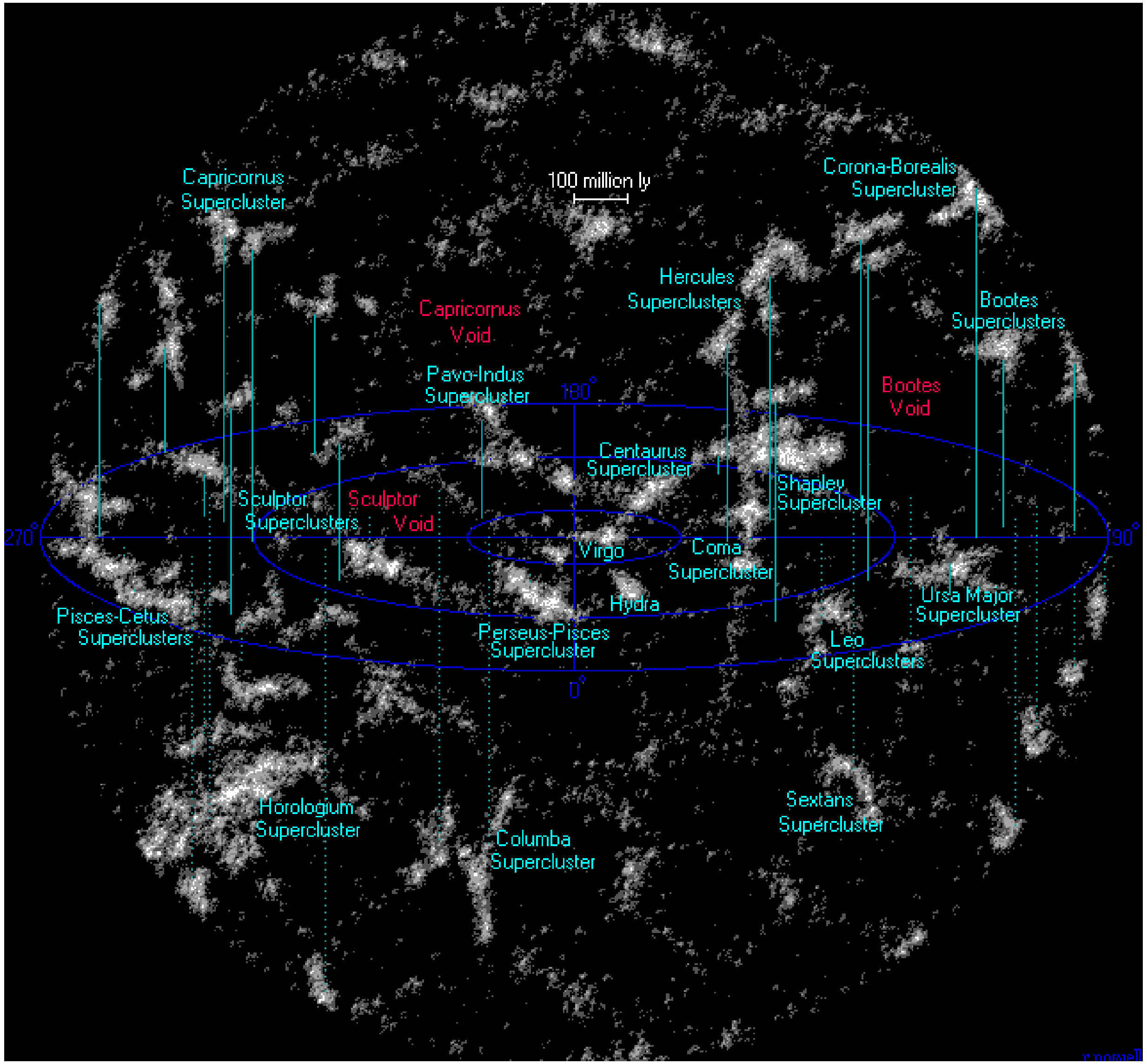
O Grupo Local



Aglomerados



Aglomerados



Escalas de distância

- Potências de 10

$10^0 = 1$

$10^1 = 10$

$10^2 = 100$

$10^3 = 1000$

...

$10^n = 10...$ (n vezes) ... 0

http://www.powersoften.com

10^0 meters

1 meter ~1 yard



This is the scale of human companionship, conversation, touch: A man is asleep on a warm October day. Around him are necessities and pleasures for mind and body. Between this image and the next frame inward, the size of the image would for once match the size of what it represents. "Of all things man is the measure," wrote Protagoras the Sophist.

10^1 meters



A man and a woman are at a picnic in the park. This picnic is the center of every picture outward to the view among the galaxies.

10^2 meters



The picnic in the park is not far from the roaring highway and the boats at their docks. The picnickers can enjoy a sense of privacy all the same, for no one else is near. Were people evenly spread over all the world's land area, these two could lay claim to six times the area of this whole square. To raise their own grain, they would need to cultivate only this grassy plot.

10^3 meters

1 kilometer 1 thousand meters



Now we look at a view that is not a maplike tracery of symbols, but a scene of familiar places within the city: Lake Shore Drive, Soldiers' Field, an airstrip, boat docks, museums.

10^4 meters

10 kilometers ~6 miles



The heart of the city appears, place of home and work for a million people. The whole structure shown here—city districts, parks, harbor—is familiar to them. The conflagration of 1871 burned the city of wooden houses which then lay within this square. Most of the detail shown is newer, though the street and railroad layout survived the fire, as in the future they will outlive most of the individual buildings.

10^5 meters

100 kilometers



The metropolitan area of Chicago nestles at the south end of the lake. On a day like this, someone walking along the street might have looked up to a blue sky; but the camera plane was flying so high it would have been hard to pick out. The lattice visible among so many blurred streets is the mile-square grid of wide Chicago boulevards.

10^6 meters

1 thousand kilometers   1 million meters



This region, viewed from a low orbit, holds the whole of Lake Michigan; the broad sheet of water, like the flat silted lands around it, was formed by continental glaciers in the most recent geological past, a few tens of thousands of years ago. The day's weather is marked by clouds arrayed in streets and clumps. Though we are looking at the homes of tens of millions of people, the work of human hands is hardly to be seen.

10^7 meters

10 thousand kilometers



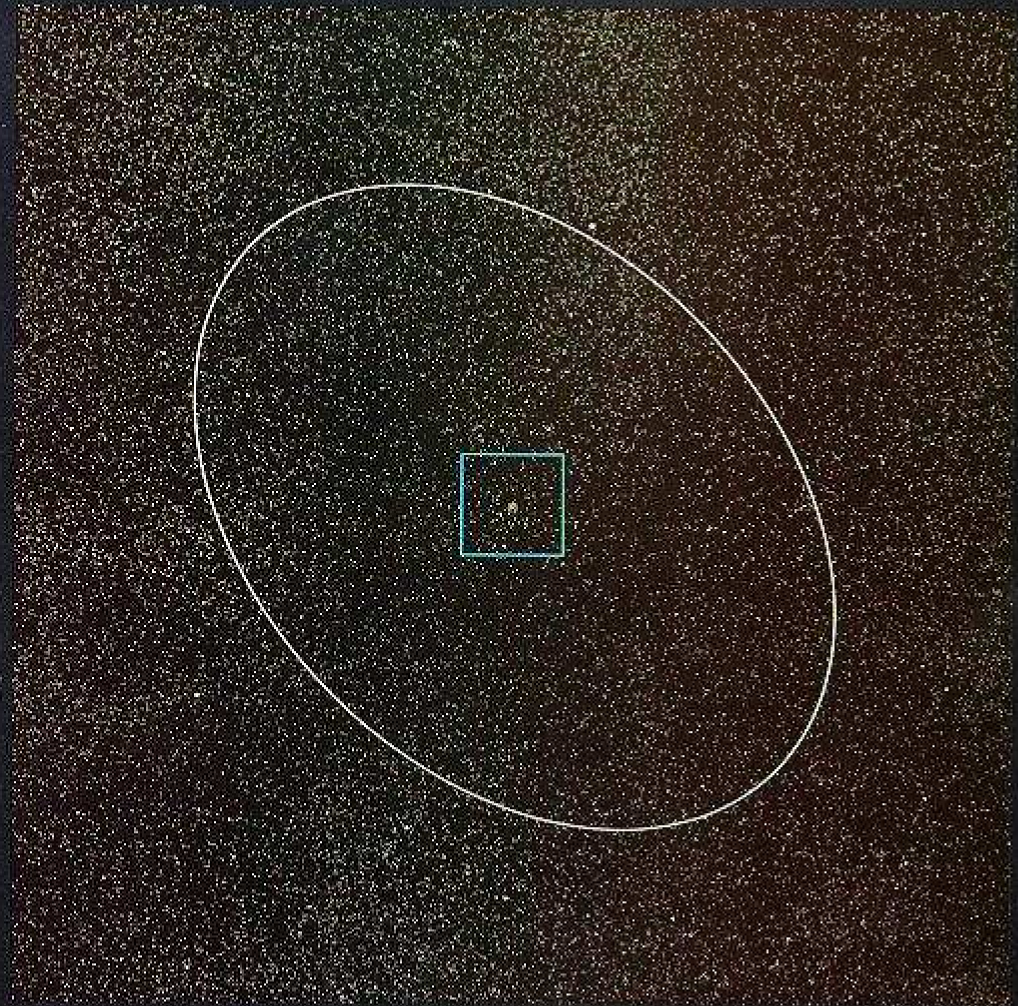
The earth in detail: blue sky, white clouds, dark seas, brown lands, a globe turning always eastward. The makers of maps had for three centuries prepared us for this sight, but it became real to eyes as well as to mind only around 1967.



The whole earth appears, isolated, elegant, and fragile. We recognize our globe in open space, a spacecraft in orbit, no Atlas and no turtles to support it. Its smooth, swift motion around the sun carries it across such a square as this every hour.

10^9 meters

1 million kilometers



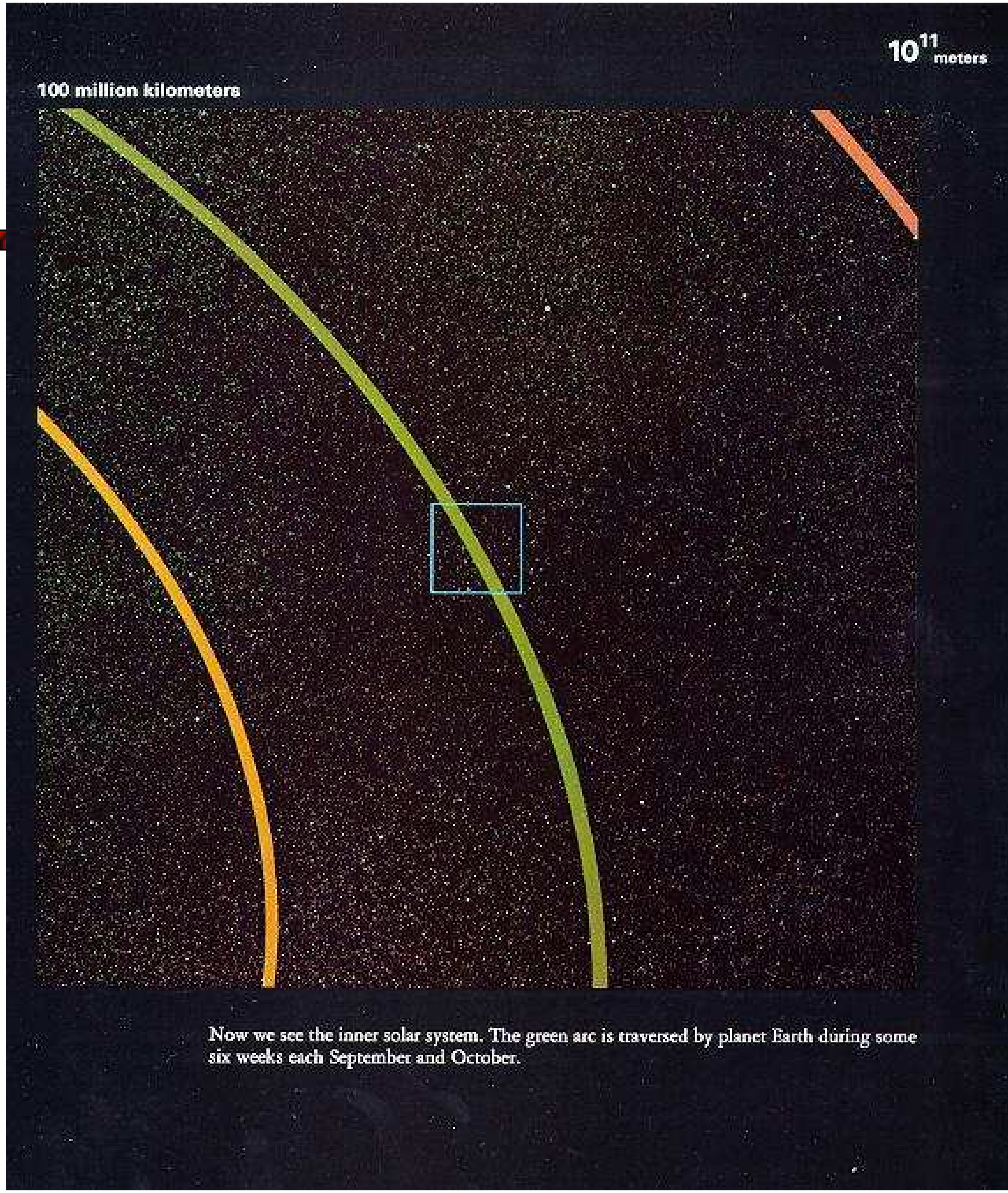
The farthest place our own kind has yet visited is the companion moon, our nearest celestial neighbor. Bright moonlight and the tides witness her proximity.

10^{10} meters

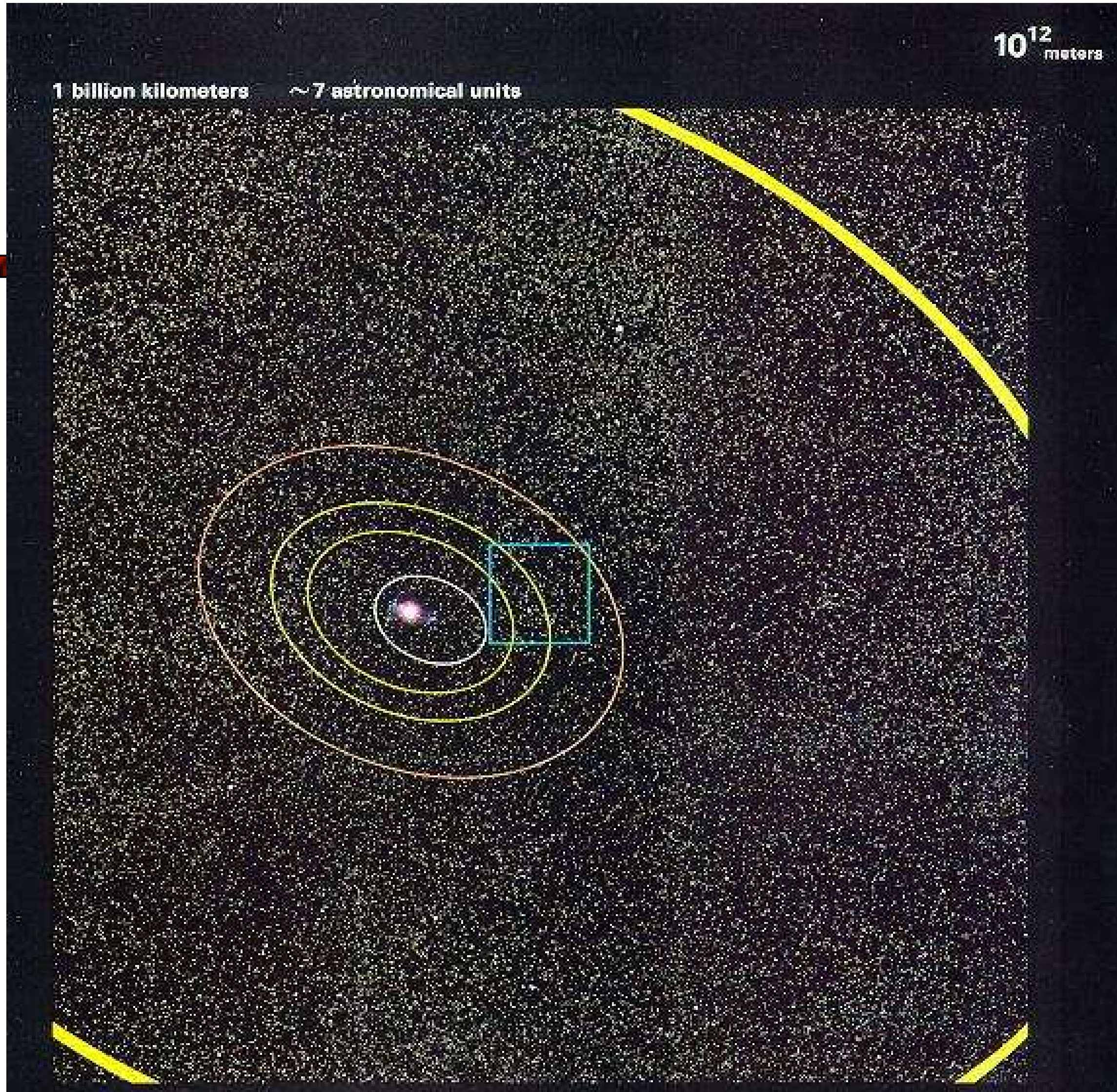
10 million kilometers



This path marks the earth's way for four days in October; within it the moon's route is indicated relative to earth. The moon at all times lies somewhere on that small ellipse which moves along with the earth in its orbit.



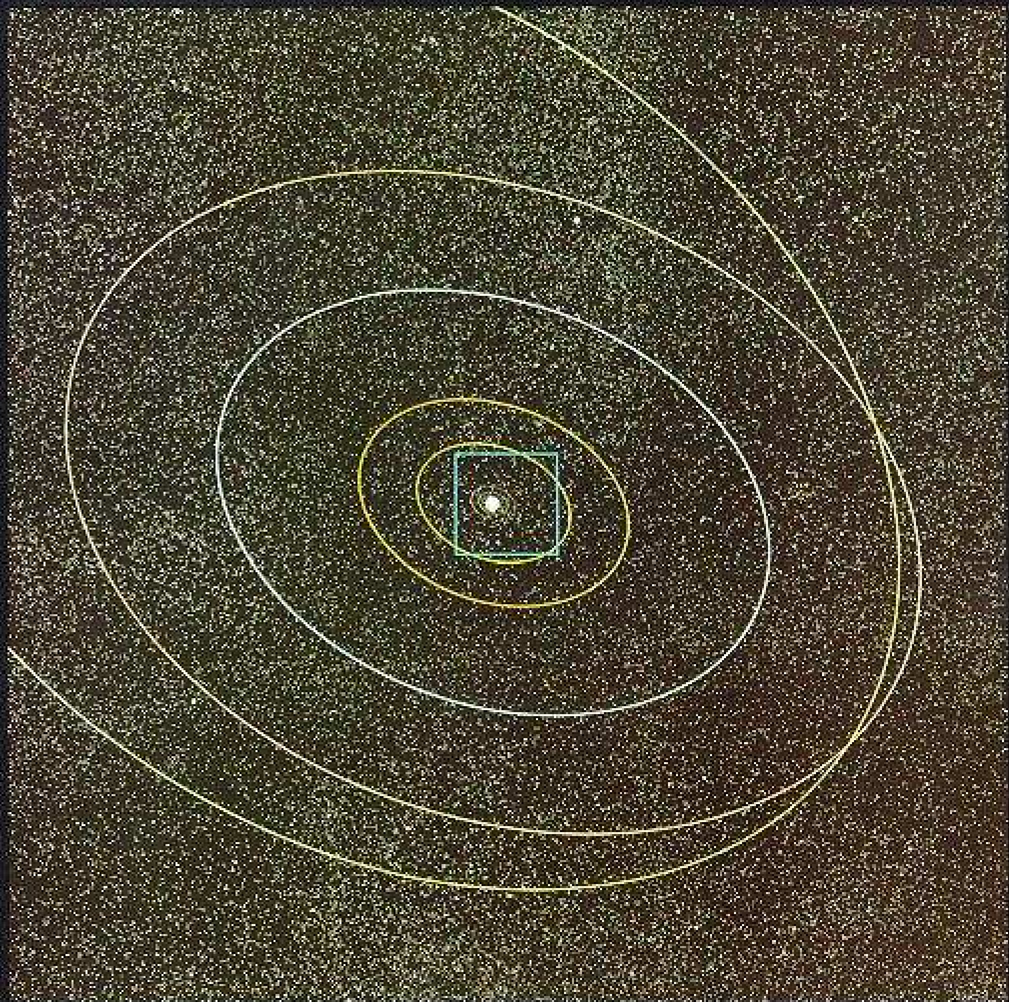
10^{11} meters
100 million kilometers
Now we see the inner solar system. The green arc is traversed by planet Earth during some six weeks each September and October.



Enclosed in the path of massive Jupiter, these are the orbits of the smaller earthlike inner planets: Mars, Earth, Venus, Mercury. Another swarm of objects too small and faint to make out without telescopic aid is present as well: Asteroids and meteors ply this darkness in the belt between the orbits of Mars and Jupiter.

10^{13} meters

10 billion kilometers



The paths of the outer planets fill this picture. That strongly tilted orbit belongs to little, awry Pluto. The four others are those of big Neptune, Uranus, Saturn, and Jupiter, with their many satellites. Between Jupiter's path and the sun run the inner planets in their smaller orbits. The planets circulate counterclockwise here, all in nearly the same plane, which we view at an angle: The planetary system, apart from Pluto, is flat as a pancake.

10^{14} meters

100 billion kilometers



All the sun's planets circulate within the small square. From earth the planets have always stood out, a few strange bright stars restlessly wandering in a skyful of unchanging patterns. Seen here from outside, the planets take on their Copernican aspect; they move around the sun on these nested ellipses, mapped by colored lines.

10^{15} meters

1 trillion kilometers



Only the sun is to be seen, against a background of fainter stars beyond. Once that was all we knew of the frontier of the sun's system. We know now that a great cloud of icy comets orbits slowly here, though invisible in the weak sunlight. We see comets only as year after year a few fall into the brighter regions near earth. There we catch sight of them, moving in the sky like temporary planets, the sun's fires boiling out their long faint tails.

~1 light-year 10 trillion kilometers

10^{16} meters



Here one central star is brighter than the rest, only because it is so much nearer. That star is the sun. The contrast between night and day, between the cold glitter of the starry sky and life-giving warmth, is the consequence simply of our planet's location next to one modest star. Once we have drawn away from the sun, we can recognize that it is one star among many stars, and all distant stars are in some way suns.

10^{17} meters

~10 light-years ~3 parsecs



Most of the matter we know is formed into stars, spheres of gas nourished by central nuclear fires that often maintain the glow for a very long time. At this point in the journey, with no star nearby, we see the realm of the stars chiefly as a distant background, no different from the night sky we view from earth. For several frames the star background remains unchanged: The visible stars are strewn so deep in space that these steps are small in comparison. Hence they cause no noticeable shifts.



A skyful of distinct stars: One among them, central, but too faint to pick out, is our sun. The star Arcturus, prominent in the northern sky of earth, shines brightly. Arcturus is intrinsically more luminous than our sun, and here we are nearer to it as well.

10^{19} meters

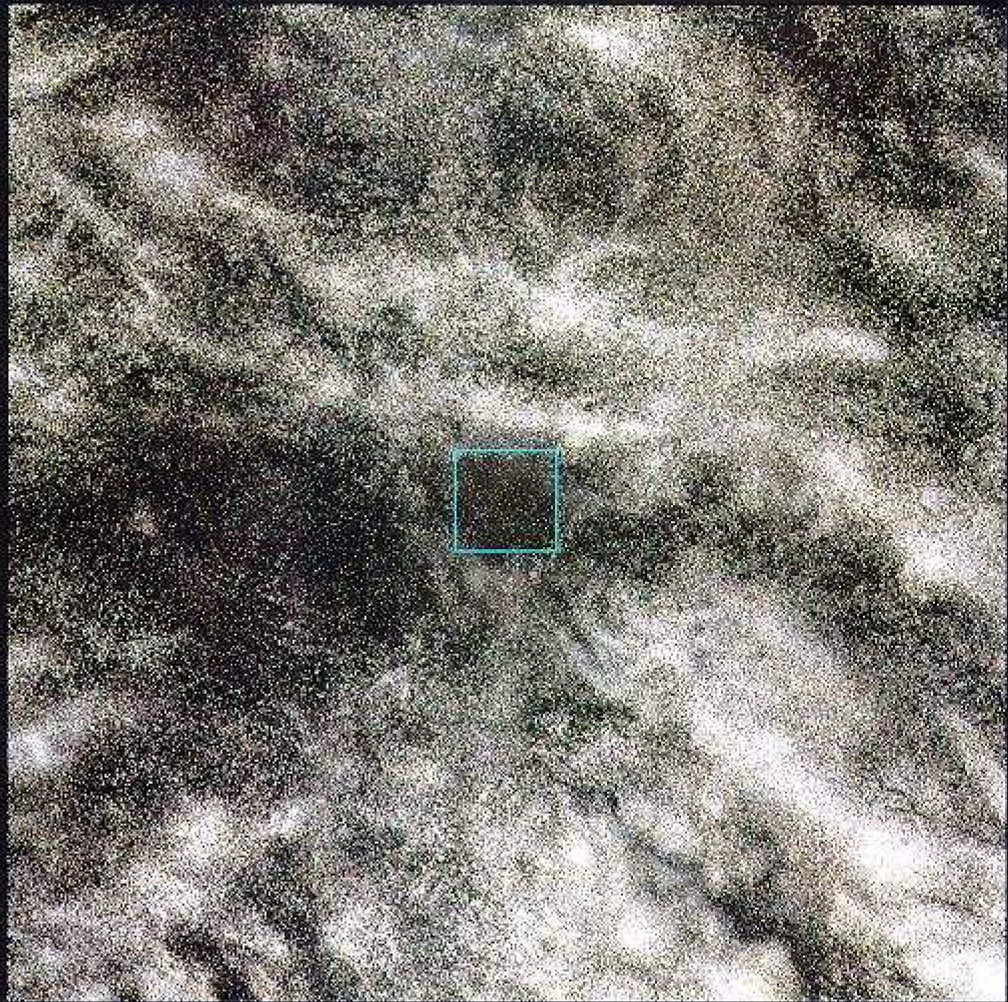
~1 thousand light-years



In this view we are within the disk of the Galaxy, right among a host of stars visible here as individuals. Almost every star of the thousand mapped by the old watchers of the sky, those who first gathered stars into constellations, lies within this square, our own galactic neighborhood. There are many other stars as well, too faint for the eye to see.

10^{20} meters

~10 thousand light-years



Clouds of stars and glowing gas, with patches of darkening dust, mark the slow-changing spiral patterns of the Galaxy disk. Our distant sun cannot be seen here, but it is in the center of the image, near the border of one spiral arm.

10^{21} meters

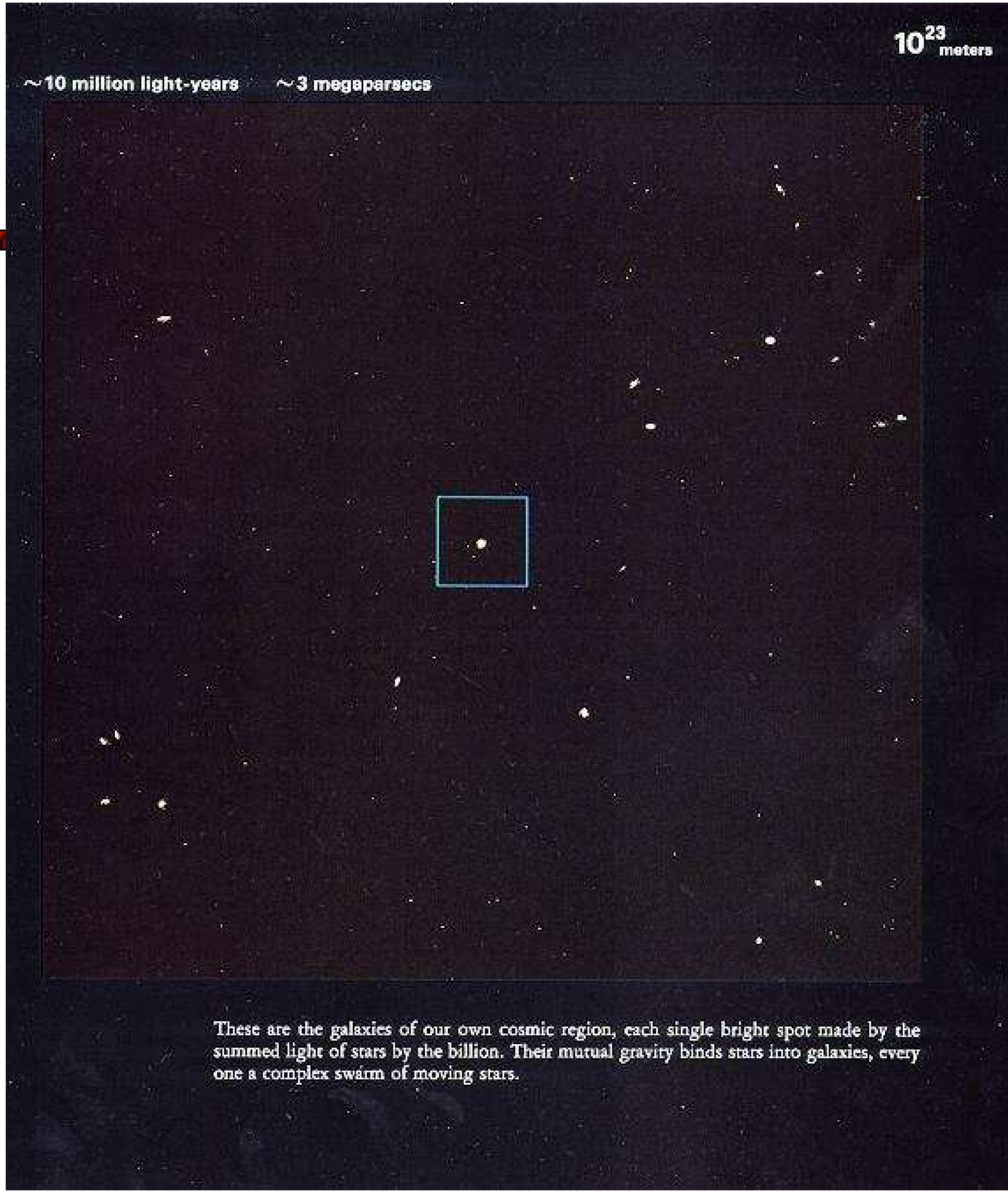
~100 thousand light-years



We look face-on directly at the Milky Way spiral. A hundred billion stars mutually bound by gravity encircle the central region, some passing close in, some in wider orbits. Our own sun swings with the rest in dignified passage clockwise about the distant galactic center, once every three hundred million years. External galaxies akin to our own are scattered throughout space as far as we can see. They too rotate slowly as they drift.



This flat circular disk is our own Galaxy, the Milky Way, with its spiral structure. It travels in space with two satellite galaxies, the irregular little Clouds of Magellan. Not many galaxies are larger than ours; nor are many seen that are smaller than the Clouds.



These are the galaxies of our own cosmic region, each single bright spot made by the summed light of stars by the billion. Their mutual gravity binds stars into galaxies, every one a complex swarm of moving stars.



We look toward our distant home in the Milky Way. But we see mostly one large intervening cluster of galaxies, called the Virgo Cluster. Galaxies as a rule associate into orbiting clusters and groups. There is reason to believe that our Milky Way is itself an outlier of the big Virgo Cluster, responsive to its steady gravitational pull: part of a supercluster. Out there beyond the Milky Way is a good-sized volume nearly devoid of noticeable galaxies.

10^{25} meters

~1 billion light-years



Most of space looks as empty as this, the glow of distant galaxies like clotted dust. This emptiness is normal; our own bright home-world is the exception. A tenfold larger view would show no new structure, no new void; the universe is roughly uniform at such dimensions. Novelty on so grand a scale is to be sought over time rather than from place to place. All swift change is in the past. This view will dim slowly, for a few billion years at least, as the faint clusters drift still farther apart.